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# (54) ELECTRIC TOOL

(57) The control circuit (14) of an electric tool (1) estimates the output interval of a sensor signal from a hole element (S) on the basis of the rotational speed of a motor (3), and sets an abnormality detection time in accordance with the estimated output interval. After actually detecting the sensor signal from the hole element (S), the control circuit (14) determines that there is an abnormality when a subsequent sensor signal is not verified within the abnormality detection time. The control circuit (14) is provided with an abnormality detection time algorithm in which the abnormality detection time is set shorter the faster the rotational speed of the motor (3), and the abnormality detection time is set longer the slower the rotational speed of the motor.

Fig.5A

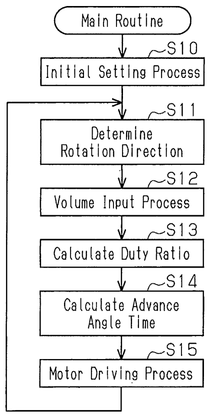



Fig.5B

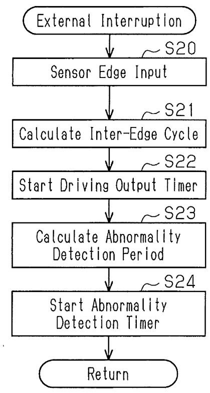



Fig.5C

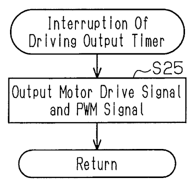
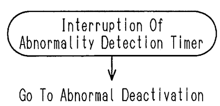



Fig.5D

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## Description

**[0001]** The present invention relates to an electric power tool that includes a brushless motor.

**[0002]** In recent years, known electric power tools employ a brushless motor as a driving source. Patent document 1 describes an electric power tool that detects the position of a rotor of a brushless motor with a rotation position detection sensor and sets the timing for energizing an armature winding of the brushless motor based on detected position information.

**[0003]** Additionally, the electric power tool of patent document 1 performs a protection operation that obviates failures in the motor caused by an abnormality in the rotor position signal detected by the rotation position detection sensor. More specifically, as shown in Fig. 6 of patent document 1, a pattern of the rotor position signal that appears under a normal situation is continuous. However, the pattern that appears may be shifted under an abnormal situation. When an abnormality is detected in the rotor position signal, the motor is stopped to perform the protection operation on the motor.

**[0004]** Patent Document 1: Japanese Laid-Open Patent Publication No. 2011-11313

**[0005]** The inventors of the present invention have studied a method for detecting an abnormality in an electric power tool. In a referential example of the method conceived by the inventors of the present invention, an interval between position information signals output from a rotation position detection sensor is set as an abnormality detection period. After an actual position information signal is detected, the occurrence of an abnormality is determined when the next position information signal cannot be detected within the abnormality detection period.

**[0006]** However, the inventors of the present invention have recognized that when the abnormality detection period is extremely short, the occurrence of an abnormality may be determined in the abnormality determination method of the referential example despite the situation being normal. On the other hand, when the abnormality detection period is extremely long, power may be supplied to a switching element of a brushless motor under a situation in which an abnormality is occurring. The inventors of the present invention have recognized that this may lead to damage of the switching element.

**[0007]** It is an object of the present invention to provide an electric power tool that allows an abnormality detection period to be set in a further suitable manner.

**[0008]** To solve the above problem, an electric power tool according to one aspect of the present invention includes a brushless motor capable of generating forward and reverse rotation, a sensor that detects a rotation position of the brushless motor and outputs a position information signal, which indicates a change in the rotation position, a drive circuit that includes a plurality of switching elements and supplies power to the brushless motor, and a controller that controls the drive circuit based on the rotation position of the brushless motor detected by the sensor. The controller estimates an output interval of the position information signal output from the sensor based on the rotation speed of the brushless motor and sets an abnormality detection period in accordance with the estimated output interval. The controller determines an occurrence of an abnormality when, after actually detecting the position information signal output from the sensor, the next position information signal is undetected within the abnormality detection period. The controller includes an abnormality period setting algorithm that sets the abnormality detection period to be shorter as the rotation speed of the brushless motor increases and sets the abnormality detection period to be longer as the rotation speed of the brushless motor decreases.

**[0009]** In a preferred example, the controller executes abnormal deactivation to stop the supply of power to the brushless motor from the drive circuit when determining the occurrence of an abnormality.

**[0010]** In a preferred example, the electric power tool includes an operation condition selector that detects one of activation and deactivation of the brushless motor in accordance with an operation performed by a user. After the abnormal deactivation is executed, when the activation of the brushless motor is selected with the operation condition selector, the controller reactivates the brushless motor.

**[0011]** In a preferred example, the controller reactivates the brushless motor by controlling the switching elements of the drive circuit with a duty ratio lower than that used before execution of the abnormal deactivation.

**[0012]** In a preferred example, the controller limits a count of the reactivation to a predetermined count.

**[0013]** In a preferred example, the controller notifies the user that the reactivation has reached the predetermined count.

**[0014]** In a preferred example, the controller performs an advance angle control on the brushless motor prior to the reactivation and does not perform the advance angle control when starting the reactivation.

**[0015]** Accordingly, the present invention provides an electric power tool in which an abnormality detection period may be set in a further suitable manner.

Fig. 1 is a partially cross-sectional view of an electric power tool of one embodiment.

Fig. 2 is a block diagram showing the electrical configuration of the electric power tool.

Fig. 3 is a block diagram of a drive circuit.

Figs. 4A and 4B are diagrams showing conditions under which signals are input to each switching element.

Figs. 5A to 5D are flowcharts showing the operation of the electric power tool.

Fig. 6 is a flowchart showing an abnormal deactivation process of the electric power tool.

Fig. 7 is a diagram showing control signal conditions corresponding to normal deactivation and abnormal deactivation.

Fig. 8 is a graph showing a method for setting an abnormality detection period relative to a rotation speed of a motor.

Fig. 9 is a graph showing a method for setting the abnormality detection period in accordance with a duty ratio.

**[0016]** An electric power tool according to one embodiment of the present invention will now be described with reference to the drawings.

**[0017]** As shown in Fig. 2, an electric power tool 1 of the embodiment includes a motor 3, which serves as a driving source, a hall element S, which serves as a sensor detecting a rotation position of the motor 3 and outputting a position information signal to indicate a change in the rotation position, a drive circuit 15, which supplies power to the motor 3, and a control circuit 14, which serves as a controller that controls the drive circuit 15.

**[0018]** In an example shown in Fig. 1, the motor 3 is accommodated in a cylindrical motor housing 2 including an open end 2a and a closed end. A rotation shaft 4 of the motor 3 extends in the axial direction of the motor housing 2 (left-right direction in Fig. 1). The open end 2a of the motor housing 2 is coupled to a dome 5, the diameter of which gradually decreases from a basal end to a distal end 5a. An output shaft 6 protrudes from the open end 2a of the dome 5. The output shaft 6 is coupled to the rotation shaft 4 of the motor 3 by a torque amplifier 7, which is accommodated in the dome 5. A distal end 6a of the output shaft 6 includes a bit attachment portion 8 that allows for the attachment of a tool (bit), which is not shown in the drawing.

**[0019]** In the example shown in Fig. 1, a trigger switch 10 is arranged in a handle 9, which is formed in the proximity of the open end 2a of the motor housing 2. The trigger switch 10 serves as an operation condition selector that selects one of activation and deactivation of the motor 3 in accordance with an operation performed by a user. The trigger switch 10 includes a main body portion 10a, which is fixed in the handle 9, and an operation portion 10b, which includes a distal end protruding from a front end of the handle 9 and is urged in the protrusion direction from the main body portion 10a. The trigger switch 10 provides the control circuit 14 with a speed signal corresponding to an amount operated by a user (pulled amount of the trigger switch 10) to adjust the rotation speed of the motor 3.

**[0020]** In the example shown in Fig. 1, a rotation direction selector 11 (forward-reverse switch) is located on a surface of the handle 9 slightly above the trigger switch 10. The rotation direction selector 11 selects a rotation direction of the motor 3 in accordance with a user operation. The rotation direction selector 11 includes an operation knob, which is movably supported. The rotation direction of the motor 3 is switched in correspondence with the movement direction of the operation knob.

**[0021]** In the example shown in Fig. 1, the electric power tool 1 is of a battery-driven type. A battery seat 12 is formed in a bottom end of the handle 9, and a battery 13 serving as a power source is attached to the battery seat 12.

**[0022]** Based on operation conditions of the trigger switch 10 and the rotation direction selector 11, the control circuit 14 controls the driving of the motor 3, which serves as a driving source, through the drive circuit 15. The drive circuit 15 generates driving power and supplies the driving power to the motor 3 in accordance with the control of the control circuit 14. As shown in Fig. 1, the control circuit 14 is, for example, accommodated in the handle 9, and the drive circuit 15 is, for example, accommodated in the motor housing 2.

**[0023]** A brushless motor is employed in the motor 3. As shown in Fig. 2, the hall element S, which is electrically connected to the control circuit 14, detects the rotation position of a rotor of the brushless motor and provides the control circuit 14 with a position information signal to indicate a change in the rotation position.

**[0024]** Fig. 3 is a schematic block diagram showing the electrical configuration of the electric power tool 1. The drive circuit 15 may include a pulse width modulation (PWM) inverter formed by connecting a plurality (for example, six) of switching elements 16 to 21.

**[0025]** In the illustrated example, the drive circuit 15 is formed by connecting in parallel a series circuit of the switching elements 16 and 19, a series circuit of the switching elements 17 and 20, and a series circuit of the switching elements 18 and 21. The switching elements 16, 17, and 18 located at an upper side are each connected to a positive terminal of the battery 13, and the switching elements 19, 20, and 21 located at a lower side are each connected to a negative terminal of the battery 13. A node between the switching elements 16 and 19, a node between the switching elements 17 and 20, and a node between the switching elements 18 and 21 are connected to motor coils 3u, 3v, and 3w of the motor 3 via connection points 22u, 22v, and 22w, respectively. The switching elements 16 to 21 each may be formed by a field effect transistor (FET).

**[0026]** The control circuit 14 may control the drive circuit 15 in accordance with rotation position information of the motor 3 based on a position information signal received from the hall element S. For example, the control circuit 14 generates a motor control signal in accordance with the rotation position information of the motor 3 and provides each of the switching elements 16 to 21 with the control signal. Each of the switching elements 16 to 21 is operated with a duty ratio (that is, ratio of on to off) of the motor control signal. The control circuit 14 changes the duty ratio for each of the switching elements 16 to 21 by appropriately changing the duty ratio of the motor control signal. The drive circuit 15 converts the DC voltage of the battery 13 into three-phase driving power and supplies the three-phase driving power to the motor 3. When the switching elements 16 to 21 are each an FET, the motor control signal may be referred to as a gate on/off signal provided to the gates of the switching elements 16 to 21.

**[0027]** The control circuit 14 of the electric power tool 1 of the embodiment outputs the motor control signal, which is provided to each of the switching elements 16 to 21 when generating rotation with the motor 3, by sequentially switching from modes A to F shown in Fig. 4A. As shown in Fig. 4B, each of the switching elements 16 to 21 is switched on and off. When activating the motor 3, the control circuit 14 performs a commutation control, which provides the motor control signal corresponding to the mode to terminals U+, U-, V+, V-, W+, and W- respectively connected to the switching elements 16 to 21. When the switching elements 16 to 21 are each an FET, the terminals U+, U-, V+, V-, W+, and W- are each connected to the gate of the corresponding switching element. By PWM controlling the motor control signal, the control circuit 14 controls the current supplied to the motor coils 3u, 3v, and 3w and controls the rotation speed of the motor 3. Here, a mode is selected from modes A to F in correspondence with a sensor signal output from the hall element S forming a rotor position detection sensor.

**[0028]** The operation of the electric power tool 1 of the embodiment will now be described with reference to Figs. 5 and 6.

**[0029]** As shown in Fig. 5A, as a main routine for controlling the driving of the motor, the control circuit 14 first performs an initial setting process (step S10). The control circuit 14 reads a signal of the rotation direction selector 11 and determines the rotation direction of the motor 3 (step S11). The control circuit 14 performs a volume input process that processes a speed signal received from the trigger switch 10 in accordance with a predetermined algorithm (step S12) and calculates the duty ratio in correspondence with the input speed signal (step S13). The control circuit 14 calculates the timing for advancing an angle based on the rotation speed of the motor 3 (step S 14) and then performs the driving process on the motor 3 (step S 15). Subsequently, steps S11 to S15 are repeated.

**[0030]** Here, in the volume input process of step S12, the control circuit 14 converts the input speed signal into a volume signal corresponding to the pulled amount of the trigger switch 10 and stores the volume signal. In the calculation of the timing for advancing the angle, when an advance angle is represented by, for example, $\alpha$°, the timing of an external interruption, that is, the timing for inputting the sensor signal, is 60° in terms of electrical angle. Thus, the control circuit 14 outputs a timer interruption signal after a delay of a time corresponding to $(60-\alpha)$° from when an external interruption is received. In this manner, the control circuit 14 may perform an advance angle control of the advance angle $\alpha$°. The timing for advancing the angle tn is calculated by the equation of $tn=(T-2*(60-\alpha))/60$.

**[0031]** An interruption process of Fig. 5B will now be described. The interruption process is triggered by an edge of the sensor signal (position information signal) output from the hall element S, which detects the rotor position of the motor 3.

**[0032]** When receiving an edge of the sensor signal from the hall element S (step S20), the control circuit 14 calculates an inter-edge period (interval between sensor signals) using a count value of the edge of the sensor signal that is input in the previous step S20 and a count value of the edge of the sensor signal that is input in the present step S20 (step S21). Then, the control circuit 14 starts a driving output timer (step S22). The control circuit 14 calculates rotation speed of the motor 3 using the inter-edge period, which is calculated in step S21, and calculates an abnormality detection period using the calculated rotation speed (step S23). For example, the control circuit 14 estimates an output interval of the sensor signal (position information signal) of the hall element S based on the calculated rotation speed and sets the abnormality detection period (detection window) in accordance with the estimated output interval. The control circuit 14 includes an abnormality period setting algorithm that sets the abnormality detection period to be longer as the calculated rotation speed decreases and shorter as the calculated rotation speed increases. The control circuit 14 may set the abnormality detection period in accordance with the abnormality period setting algorithm. For example, as shown in Fig. 8, the abnormality period setting algorithm may include a function and a map indicating the relationship between the calculated rotation speed and the abnormality detection period.

**[0033]** The control circuit 14 starts an abnormality detection timer (step S24) and returns to the main routine.

**[0034]** The control circuit 14 stops the driving output timer when the advance angle time, which is calculated in step S 13 of the main routine, elapses, and starts an interruption process of Fig. 5C. The control circuit 14 outputs a motor driving signal and a PWM signal (step S25). Then, the control circuit 14 returns to the main routine.

**[0035]** The control circuit 14 determines an occurrence of abnormality when the abnormality detection period elapses before the edge of the next sensor signal is input. Then, the control circuit 14 stops the abnormality detection timer and performs an abnormal deactivation process as an interruption process shown in Fig. 5D. For example, the control circuit 14 executes abnormal deactivation in step S30. The abnormal deactivation may be referred to as a driving power supply suspension triggered by an abnormal detection or abnormality determination. In this case, in an example shown in Fig. 7, during the abnormal deactivation, the motor control signal having the H level is provided to each of the terminals U+, U-, V+, V-, W+, and W- to stop the output from each of the switching elements 16 to 21. This suspends power supply to the motor 3. In a normal deactivation, the switching elements corresponding to the terminals U+, V+, and W+ are switched off but the switching elements corresponding to the terminals U-, V-, and W- are switched on. The control circuit 14 may count abnormal deactivations and store the abnormal deactivation count. The stored count value may be reset through predetermined procedures.

**[0036]** After the abnormal deactivation, the control circuit 14 determines whether or not the trigger switch 10 has been activated (pulled) (step S31). If the trigger switch 10 is deactivated (step S31: NO), the control circuit 14 continues the abnormal deactivation state (step S32).

**[0037]** If the trigger switch 10 has been activated (step S31: YES), the control circuit 14 determines whether or not the abnormal deactivation count has exceeded a predetermined count (for example, ten) (step S33). If the abnormal deactivation count has exceeded the predetermined count (step S33: YES), the control circuit 14 continues the abnormal deactivation state.

**[0038]** If the abnormal deactivation count is less than or equal to the predetermined count (step S33: NO), the control circuit 14 performs the volume input process, which processes a speed signal of the trigger switch 10 in accordance with the predetermined algorithm (step S34). The control circuit 14 calculates the duty ratio in correspondence with the input speed signal (step S35).

**[0039]** Then, the control circuit 14 compares the duty ratio calculated in step S35 with the duty ratio used before the abnormal deactivation (step S36). If the duty ratio calculated in step S35 is greater than or equal to the duty ratio used before the abnormal deactivation (step S36: YES), the control circuit 14 changes the calculated duty ratio to a duty ratio that is lower than the duty ratio used before the abnormal deactivation and reactivates the motor 3 (step S37). If the duty ratio calculated in step S35 is lower than the duty ratio used before the abnormal deactivation (step S36: NO), the control circuit 14 reactivates the motor with the calculated duty ratio (that is, a duty ratio lower than the duty ratio used before the abnormal deactivation) (step S38). Under this condition, the speed of the motor 3 is low due to the abnormal deactivation. Thus, if the motor 3 were to be activated with the same duty ratio as that used before the abnormal deactivation, a current overshoot may suddenly rotate the bit and apply an unexpected repercussion to the user. To cope with this problem, after the abnormal deactivation, the motor 3 is reactivated with a duty ratio lower than the duty ratio that was used before the abnormal deactivation. This prevents or reduces current overshoot and unexpected repercussions, and improves safety of the electric power tool 1.

**[0040]** Preferably, during the reactivation in step S37 or S38, the control circuit 14 may not perform the advance angle control. After activating the motor 3 in step S37 or S38, the control circuit 14 returns to step S11 of the main routine shown in Fig. 5A.

**[0041]** The advantages of the present embodiment will now be described.

(1) The control circuit 14 estimates the output interval between sensor signals, which are output from the hall element S, based on the rotation speed of the motor 3 and sets the abnormality detection period in accordance with the estimated output interval. After a sensor signal output from the hall element S is actually detected, the control circuit 14 determines the occurrence of an abnormality when the next sensor signal is not detected within the abnormality detection period. The control circuit 14 sets the abnormality detection period to be shorter as the rotation speed of the motor 3 increases and longer as the rotation speed of the motor 3 decreases. In this manner, when the abnormality detection period is set to be shorter as the rotation speed increases, the output interval of the sensor signal is shortened in correspondence with the rotation speed of the motor 3. Thus, an abnormality may be appropriately detected. In addition, the short abnormality detection period may limit the supply of power to the switching elements 16 to 21 of the motor 3 during an abnormal situation and obviate damage of the switching elements 16 to 21. In contrast, when the abnormality detection period is set to be longer as the rotation speed of the motor 3 decreases, the output interval is prolonged in correspondence with the rotation speed of the motor 3. This avoids the determination of the occurrence of an abnormality during a normal situation.

(2) When determining the occurrence of an abnormality, the control circuit 14 executes abnormal deactivation to stop the motor 3 by stopping the supply of power to the motor 3 from the drive circuit 15. This limits the flow of current to the switching elements 16 to 21 during the abnormal condition and obviates damage of the switching elements 16 to 21.

(3) The control circuit 14 is connected to the trigger switch 10, which selects one of activation and deactivation of the motor 3 in accordance with an operation by a user. When activation of the motor 3 is selected with the trigger switch 10 after executing abnormal deactivation to the motor 3, the control circuit 14 reactivates the motor 3. In this configuration, even when the load on the electric power tool 1 temporarily increases and the rotation generated with the motor 3 is momentarily changed to an abnormal condition, the motor 3 is reactivated when returned to the normal condition. This relatively shortens interruptions of a task performed by an operator and improves convenience for a user.

(4) The control circuit 14 controls the switching ele-

ments 16 to 21 of the drive circuit 15 with a duty ratio that is lower than the duty ratio used before the abnormal deactivation and reactivates the motor 3. Under this condition, the speed of the motor 3 is low due to the abnormal deactivation. Thus, if the motor 3 were to be activated with the same duty ratio as that used before the abnormal deactivation, a current overshoot may suddenly rotate the bit and apply an unexpected repercussion to the user. To cope with this problem, after the abnormal deactivation, the motor 3 is reactivated with the duty ratio that is lower than the duty ratio used before the abnormal deactivation (refer to steps S37 and S38). This prevents or reduces current overshoot and unexpected repercussions, and improves safety of the electric power tool 1.

(5) In a preferred example, the control circuit 14 limits the reactivation count to the predetermined count. This reduces breakage of the switching elements 16 to 21 resulting from overuse when reactivations of the motor 3 and abnormal detections are repeated.

(6) In a preferred example, the control circuit 14 performs the commutation control on the motor 3 prior to reactivation and does not perform the advance angle control when starting the reactivation. When the reactivation is started, particularly, when the reactivation is started immediately after abnormal deactivation, rotation of the motor 3 is unstable. Thus, the advance angle control is suspended during the unstable rotation. This quickly stabilizes the rotation condition of the motor 3.

**[0042]** The above embodiment may be modified as follows.

**[0043]** The above embodiment is configured to change the abnormality detection period in accordance with the rotation speed of the motor 3. Additionally, as shown in Fig. 9, the abnormality detection period may be changed by taking into consideration the duty ratio. For example, the control circuit 14 may include an abnormality period setting algorithm that shortens the abnormality detection period when the duty ratio is large, and prolongs the abnormality detection period when the duty ratio is small.

**[0044]** The above embodiment is configured to limit the reactivation count to the predetermined count. However, there is no limit to such a configuration.

**[0045]** The above embodiment is configured not to perform the advance angle control on the motor 3 when starting reactivation. However, there is no limit to such a configuration.

**[0046]** Although not described in the above embodiment, the control circuit 14 may notify a user that the number of reactivations of the motor 3 has reached the predetermined number of times. This configuration allows the user to be aware of an abnormal situation. There is no special limitation for the notification method, however, for example, a notification may be performed through a visual, audial, or tactile notification unit that may be arranged in the electric power tool 1.

**[0047]** The preferred example and modified examples may be appropriately combined.

DESCRIPTION OF REFERENCE SYMBOLS

**[0048]**

| | |
|---|---|
| 1 | Electric Power Tool |
| 3 | Motor (Brushless Motor) |
| 10 | Trigger Switch Serving As Operation Condition Selector |
| 11 | Rotation Direction Selector |
| 14 | Control Circuit Serving As Controller |
| 15 | Drive Circuit |
| 16 to 21 | Switching Elements |
| S | Hall Element Serving As Sensor |

## Claims

**1.** An electric power tool including:

a brushless motor capable of generating forward and reverse rotation;
a sensor that detects a rotation position of the brushless motor and outputs a position information signal, which indicates a change in the rotation position;
a drive circuit that includes a plurality of switching elements and supplies power to the brushless motor; and
a controller that controls the drive circuit based on the rotation position of the brushless motor detected by the sensor, the electric power tool being **characterized in that**:

the controller estimates an output interval of the position information signal output from the sensor based on the rotation speed of the brushless motor and sets an abnormality detection period in accordance with the estimated output interval;
the controller determines an occurrence of an abnormality when, after actually detecting the position information signal output from the sensor, the next position information signal is undetected within the abnormality detection period; and
the controller includes an abnormality period setting algorithm that sets the abnormality detection period to be shorter as the rotation speed of the brushless motor increases and sets the abnormality detection period to be longer as the rotation speed of the brushless motor decreases.

2. The electric power tool according to claim 1, **characterized in that** the controller executes abnormal deactivation to stop the supply of power to the brushless motor from the drive circuit when determining the occurrence of an abnormality.

3. The electric power tool according to claim 2, **characterized by**:

   an operation condition selector that detects one of activation and deactivation of the brushless motor in accordance with an operation performed by a user,
   wherein after the abnormal deactivation is executed, when the activation of the brushless motor is selected with the operation condition selector, the controller reactivates the brushless motor.

4. The electric power tool according to claim 3, **characterized in that** the controller reactivates the brushless motor by controlling the switching elements of the drive circuit with a duty ratio lower than that used before execution of the abnormal deactivation.

5. The electric power tool according to claim 3 or 4, **characterized in that** the controller limits a count of the reactivation to a predetermined count.

6. The electric power tool according to claim 5, **characterized in that** the controller notifies the user that the reactivation has reached the predetermined count.

7. The electric power tool according to any one of claims 3 to 6, **characterized in that** the controller performs an advance angle control on the brushless motor prior to the reactivation and does not perform the advance angle control when starting the reactivation.

Fig.1

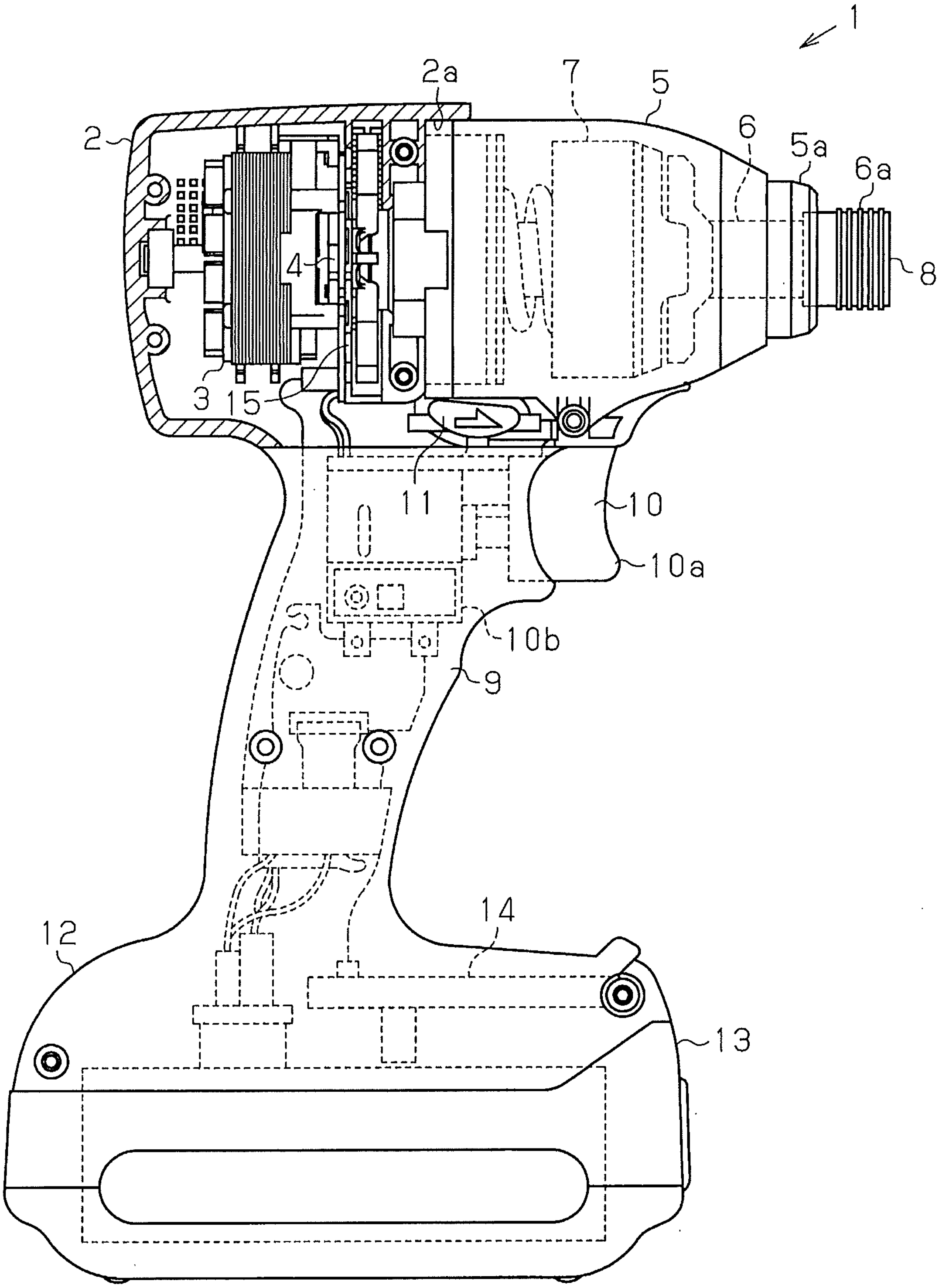


Fig.2

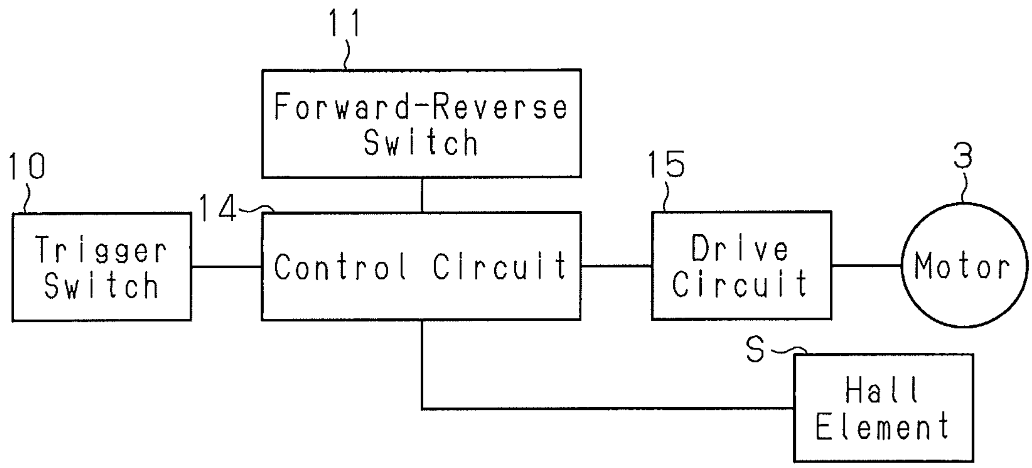

11
Forward-Reverse Switch
10
Trigger Switch
14
Control Circuit
15
Drive Circuit
3
Motor
S
Hall Element

Fig.3

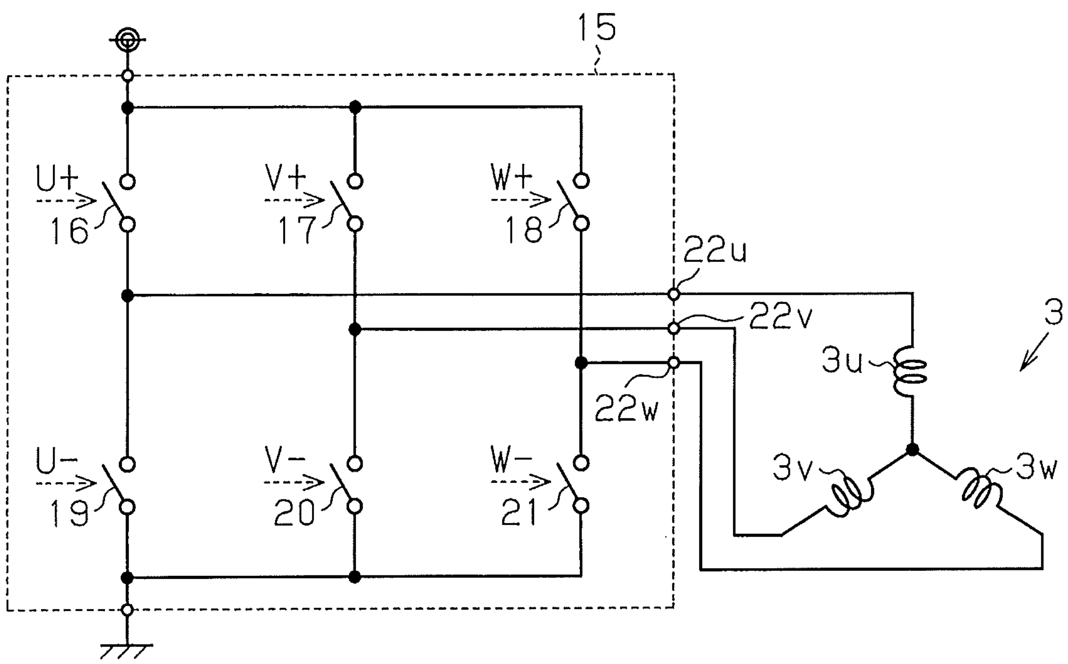

15
U+
16
V+
17
W+
18
22u
22v
22w
3
3u
3v
3w
U-
19
V-
20
W-
21

Fig.4A

| Mode | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| U+ | L | L | H | H | H | H |
| U- | H | H | H | L | L | H |
| V+ | H | H | L | L | H | H |
| V- | L | H | H | H | H | L |
| W+ | H | H | H | H | L | L |
| W- | H | L | L | H | H | H |

Fig.4B

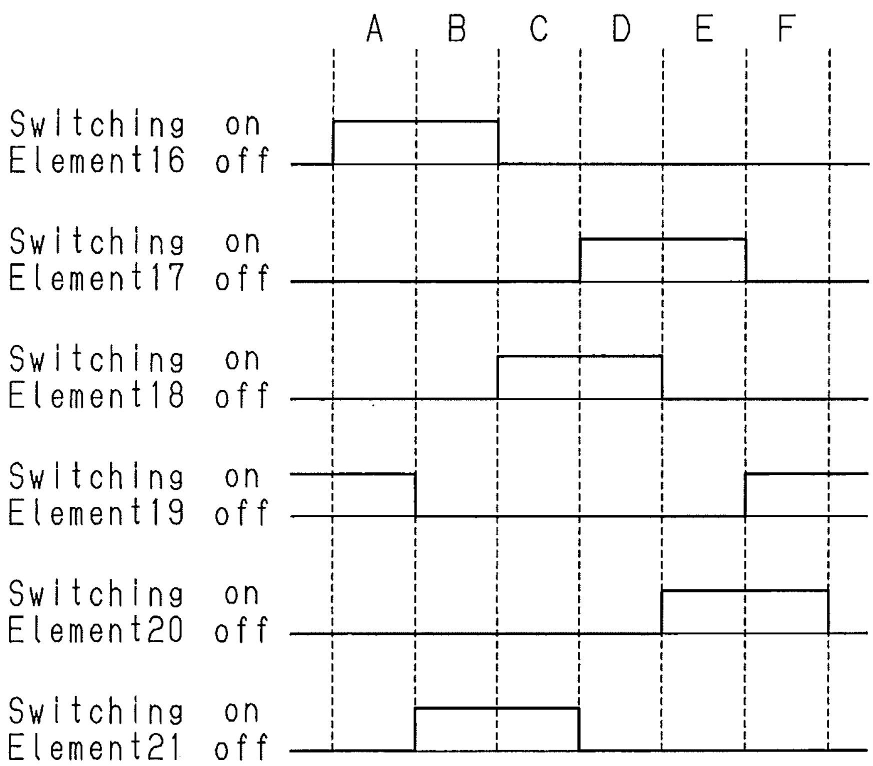


Fig.5A

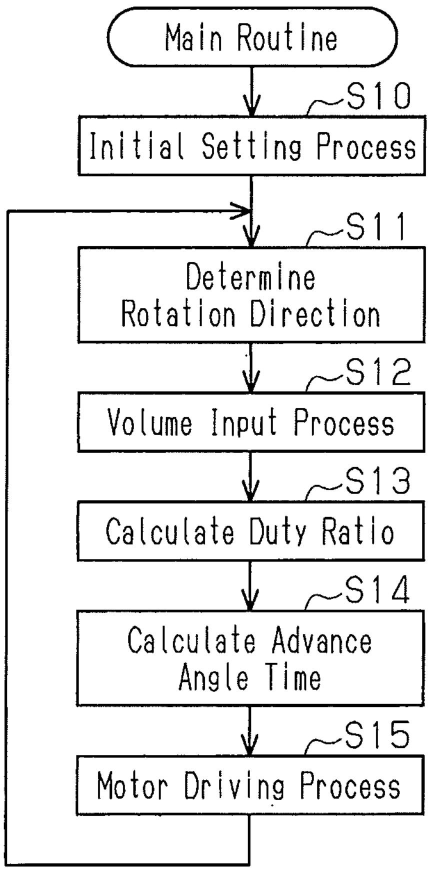



Fig.5B

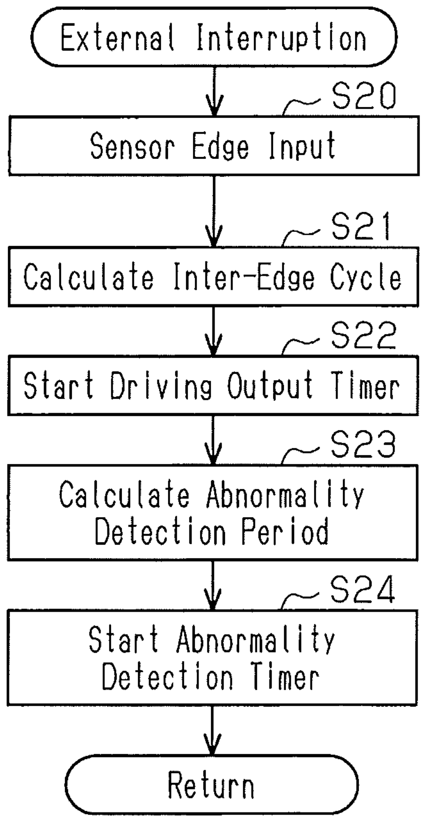



Fig.5C

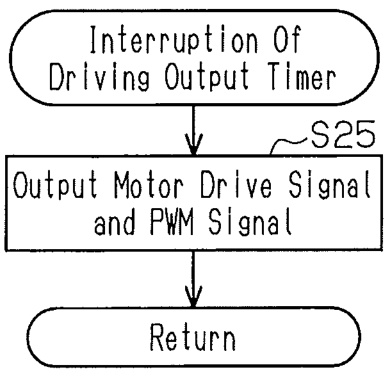



Fig.5D

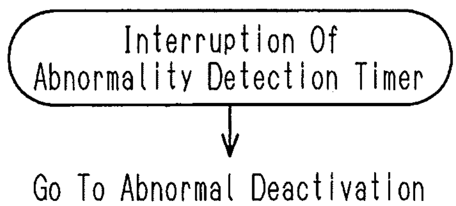


Fig.6

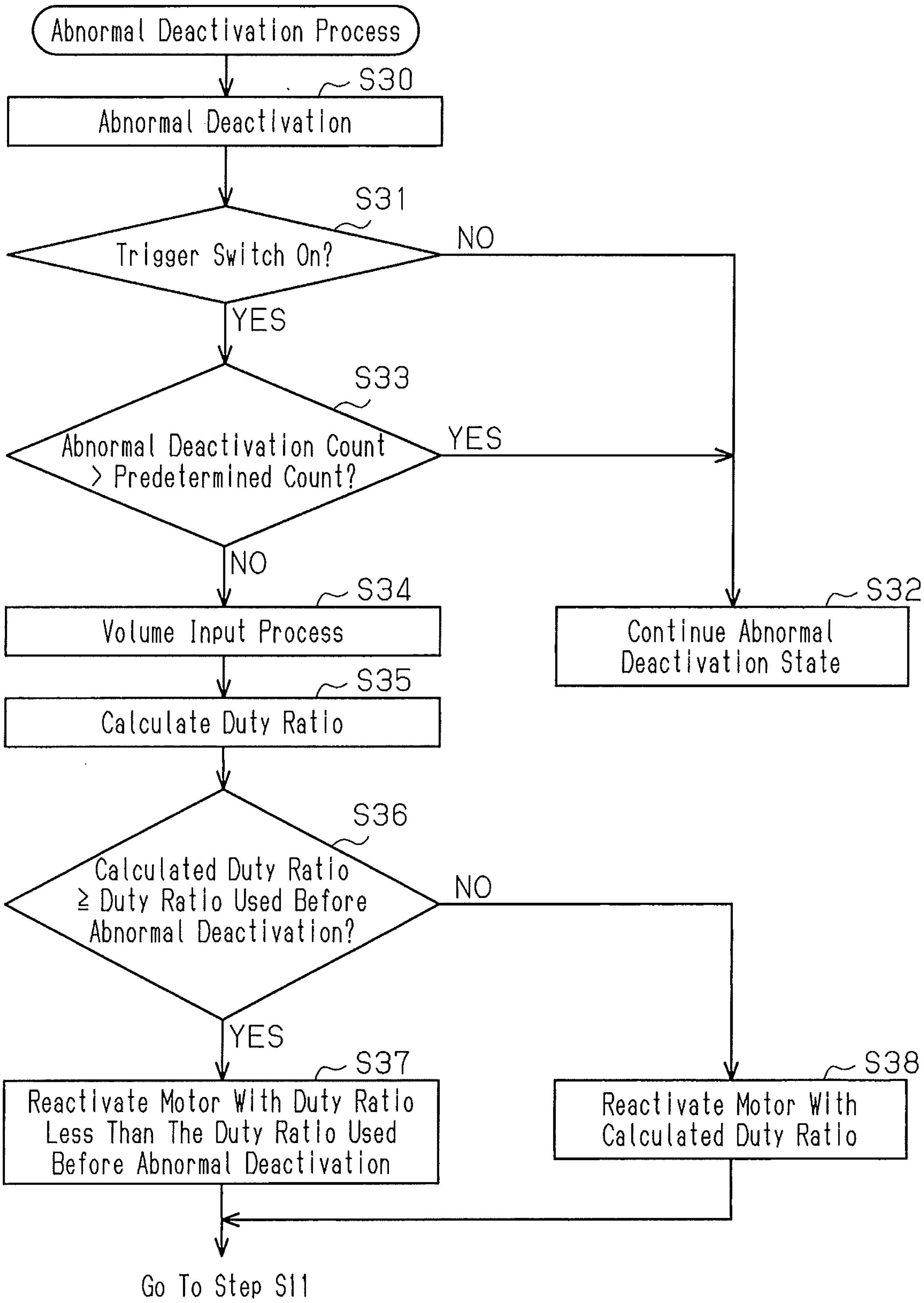

Abnormal Deactivation Process
S30
Abnormal Deactivation
S31
Trigger Switch On?
NO
YES
S33
Abnormal Deactivation Count
> Predetermined Count?
YES
NO
S34
Volume Input Process
S32
Continue Abnormal
Deactivation State
S35
Calculate Duty Ratio
S36
Calculated Duty Ratio
≥ Duty Ratio Used Before
Abnormal Deactivation?
NO
YES
S37
Reactivate Motor With Duty Ratio
Less Than The Duty Ratio Used
Before Abnormal Deactivation
S38
Reactivate Motor With
Calculated Duty Ratio
Go To Step S11

Fig.7

| | Normal Deactivation | Abnormal Deactivation |
|---|---|---|
| U+ | H | H |
| V+ | H | H |
| W+ | H | H |
| U− | L | H |
| V− | L | H |
| W− | L | H |

Fig.8

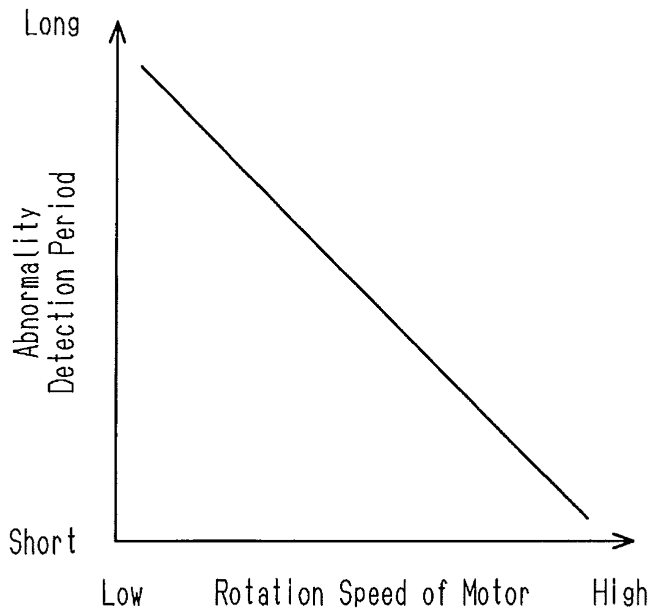
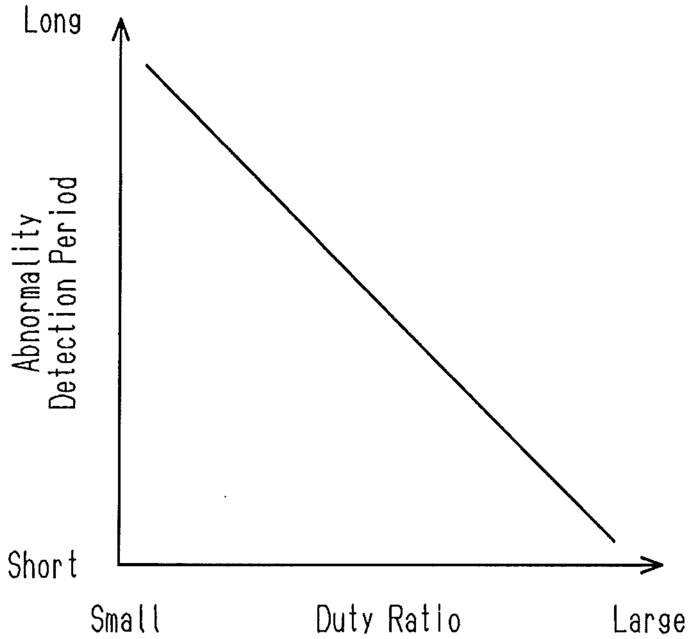


Fig.9


Long
Abnormality
Detection Period
Short
Small
Duty Ratio
Large

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2013/000947

A. CLASSIFICATION OF SUBJECT MATTER
*B25F5/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B25F5/00

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

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1922-1996 | Jitsuyo Shinan Toroku Koho | 1996-2013 |
| Kokai Jitsuyo Shinan Koho | 1971-2013 | Toroku Jitsuyo Shinan Koho | 1994-2013 |

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>Y | JP 2009-165280 A (Makita Corp.), 23 July 2009 (23.07.2009), paragraphs [0009], [0011] to [0027]; all drawings & US 2010/0308764 A1 & EP 2219288 A1 & WO 2009/087834 A1 & CN 101911468 A | 1-2<br>3-7 |
| Y | JP 2011-011313 A (Hitachi Koki Co., Ltd.), 20 January 2011 (20.01.2011), paragraphs [0064] to [0068]; all drawings (Family: none) | 3-7 |
| Y | JP 2008-023645 A (Makita Corp.), 07 February 2008 (07.02.2008), paragraphs [0017] to [0024]; all drawings (Family: none) | 4-7 |

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

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 28 March, 2013 (28.03.13) | 09 April, 2013 (09.04.13) |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Japanese Patent Office | |
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### Patent documents cited in the description


- JP 2011011313 A **[0004]**