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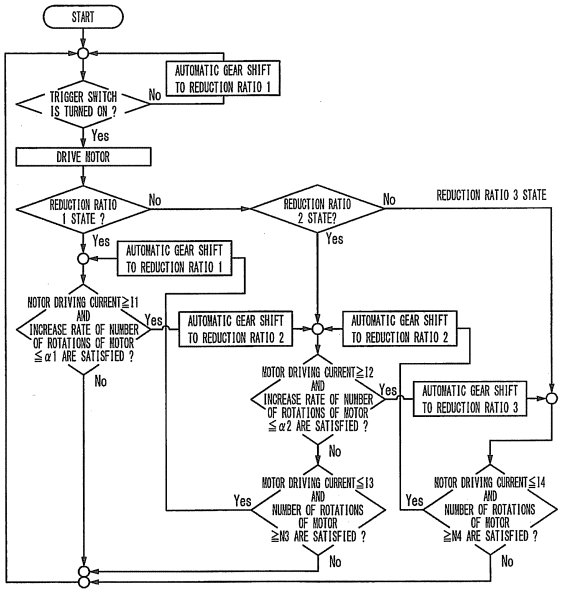
(54) ## ELECTRIC TOOL

(57) An electric tool of the present invention includes a transmission for switching a reduction ratio between a motor as a rotational power source and an output unit rotatably driven by the motor. The electric tool further includes a driving state detecting means detecting at least two driving states, of driving states that vary in response to a magnitude of a load when the output unit is driven, and a controlling means making the transmission switch the reduction ratio when the at least two driving states detected by the driving state detecting means satisfy predetermined conditions preset for the respective driving states.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to electric tools, particularly to an electric tool including a gear shifting means.

BACKGROUND ART

[0002] When screwing or punching work is performed with an electric tool that allows the reduction ratio to be switched in response to a magnitude of a load of the work, the following operation is efficient:

> the work is started at a low reduction ratio, namely by low-torque high-speed rotation, then the reduction ratio is increased to cause gear shift to a high-torque low-speed rotation side, and the work is performed by the high-torque low-speed rotation.

When the gear shift for switching the reduction ratio is performed manually, however, a worker must set the reduction ratio to be low before the start of the work, and must perform a switching operation to a high reduction ratio side during the work. The burden on the worker is thus great.

[0003] There is an electric tool where the gear shift is automatically performed in response to variation in load torque. However, an electric tool that performs automatic gear shift only with a mechanical mechanism has a complex structure and requires high cost. An electric tool that detects the load torque with a torque sensor and electromagnetically performs the gear shift requires additional cost for the torque sensor.

[0004] In the electric tools disclosed in Patent literature 1 and Patent literature 2, motor current is monitored. When the motor current exceeds a predetermined value, increase in load torque is determined and the reduction ratio is switched. In this case, the cost increase for automatic gear shift can be suppressed.

[0005] In this case, the operation state is determined based on only the motor current. Therefore, these electric tools can malfunction due to a rush motor current (see Fig. 8(a)) at the start of the motor. In order to address this problem, a method is also proposed in which the motor current is not used for the determination for a predetermined time after the start of the motor. In this method, however, in the case where a load for causing motor lock is charged from the start of the motor, excessive current flows through the motor for the predetermined time and the motor can be damaged.

[0006] A rush motor current flows also when the motor rotation speed is rapidly increased by a rapid trigger switch operation (see Fig. 8(b)). A malfunction where the rush motor current causes automatic gear shift can occur.

[0007] In addition, when the temperature increases, an N-T (number of rotations - torque) characteristic of the motor varies (decreases). Therefore, when the automatic switching is determined based on only the motor current, the torque when the reduction ratio is switched decreases gradually with increase in temperature of the motor, and the working time at a low-speed rotation increases to reduce the working speed.

PRIOR ART DOCUMENTS

PATENT LITERATURE

[0008]

> Patent literature 1: Japanese Unexamined Patent Application Publication No. 2009-78349
> Patent literature 2: Japanese Unexamined Patent Application Publication No. 2009-56590

SUMMARY OF THE INVENTION

PROBLEMS TO BE RESOLVED BY THE INVENTION

[0009] The present invention addresses such a problem, and provides an electric tool capable of inexpensively and appropriately switching the reduction ratio in response to increase in load.

MEANS OF SOLVING THE PROBLEMS

[0010] An electric tool of the present invention includes a transmission for switching a reduction ratio between a motor as a rotational power source and an output unit rotatably driven by the motor. The electric tool includes the following elements:

> a driving state detecting means detecting at least two driving states, of driving states that vary in response to a magnitude of a load when the output unit is driven; and
> a controlling means making the transmission switch the reduction ratio when the at least two driving states detected by the driving state detecting means satisfy predetermined conditions preset for the at least two driving states, respectively.

[0011] In this case, automatic gear shift is performed only when a plurality of conditions are satisfied. Therefore, the possibility of causing automatic gear shift with an undesired timing or an inappropriate timing can be reduced comparing with the case where automatic gear shift is performed solely by satisfying a single condition.

[0012] In this case, as a driving state to be compared with each predetermined condition, the controlling means may employ a driving state that differs between an operation of switching the reduction ratio from the low reduction ratio side to the high reduction ratio side and an operation of switching the reduction ratio from the high reduction ratio side to the low reduction ratio side.

[0013] As the at least two driving states detected by the driving state detecting means, a motor driving current value, and the number of rotations of the motor or an increase rate of the number of rotations of the motor can be appropriately employed. The electric tool where malfunction is neither caused by a rush current at the start of the motor nor by a rush current by rapid variation of the number of rotations of the motor can be obtained with a simple configuration.

[0014] The controlling means, preferably, switches the reduction ratio from the low reduction ratio side to the high reduction ratio side when the motor driving current value and the increase rate of the number of rotations of the motor satisfy the respective predetermined conditions. The controlling means, preferably, switches the reduction ratio from the high reduction ratio side to the low reduction ratio side when the motor driving current value and the number of rotations of the motor satisfy the respective predetermined conditions.

[0015] The electric tool includes a motor driving temperature detecting means detecting the temperature of the motor or the temperature of a motor driving circuit for the motor, wherein the controlling means corrects the predetermined conditions for switching of the reduction ratio in response to a motor driving temperature detected by the motor driving temperature detecting means. The electric tool includes a power supply temperature detecting means detecting the temperature of the power supply, wherein the controlling means corrects the predetermined conditions for switching of the reduction ratio in response to the power supply temperature detected by the power supply temperature detecting means.

[0016] In the former case, it is possible to reduce variation in working speed to provide stable work. If one of the driving states detected by the driving state detecting means is the motor driving current value, preferably, the controlling means increases the predetermined condition for the motor driving current value when the motor driving temperature detected by the motor driving temperature detecting means is higher than a predetermined value. It is possible to prevent reduction in torque during gear shift and to prevent reduction in working speed.

[0017] In the latter case, it is possible to reduce the load on the power supply, prevent battery degradation when the power supply is a battery, and prevent the temperature increase of the battery from immediately causing forced stop of the motor. Therefore, safe work can be continued. If one of the driving states detected by the driving state detecting means is the motor driving current value, preferably, the controlling means decreases the predetermined condition for the motor driving current value when the power supply temperature detected by the power supply temperature detecting means is higher than a predetermined value. It is possible to reduce the load on the battery, and restrict the temperature increase. It is possible to prevent battery degradation and secure the safety of the work.

[0018] The electric tool further includes a motor driving temperature detecting means detecting the temperature of the motor or the temperature of a motor driving circuit for the motor, and a power supply temperature detecting means detecting the temperature of the power supply.

[0019] The controlling means may correct the predetermined conditions in response to the motor driving temperature detected by the motor driving temperature detecting means and the power supply temperature detected by the power supply temperature detecting means. When, at a high power supply temperature, the correction of the predetermined condition based on the power supply temperature has higher priority than the correction of the predetermined condition based on the motor driving temperature, the increase in battery temperature does not immediately cause motor forced stop. Therefore, the safety of the work is secured advantageously.

[0020] The electric tool may employ the smaller one of the following correction values:

the correction value of the predetermined condition for the motor driving current value when the motor driving temperature detected by the motor driving temperature detecting means is higher than a predetermined value; and

the correction value of the predetermined condition for the motor driving current value when the power supply temperature detected by the power supply temperature detecting means is higher than a predetermined value.

It is possible to reduce the load of both the motor and battery.

EFFECTS OF THE INVENTION

[0021] In the present invention, the possibility of causing automatic gear shift with an undesired timing or an inappropriate timing can be reduced comparing with the case where automatic gear shift is performed solely by satisfying a single condition. Therefore, comfortable work can be performed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

Fig. 1 is a flowchart showing the operation of an example in an embodiment of the present invention.
Fig. 2 is a block diagram of the example in the embodiment of the present invention.
Fig. 3 is an explanatory diagram showing the relationship between a motor characteristic and temperature.
Fig. 4 is a block diagram of another example.
Fig. 5 is a flowchart showing the operation of the another example.
Fig. 6 is a block diagram of yet another example.
Fig. 7 is a flowchart showing the operation of the yet

another example.

Fig. 8(a) and 8(b) are explanatory diagrams of rush currents.

DESCRIPTION OF THE EMBODIMENTS

[0023] The present invention is described based on the examples of the drawings in detail. An electric tool of Fig. 2 is an electric drill driver where a normally/inversely rotational motor 10 is used as the power source. The rotation output of the motor 10 is sent to an output unit 12 via a transmission 11 that has a gear shift function of switching the reduction ratio. In Fig. 2, the reference number 18 denotes a battery pack.

[0024] The transmission 11 can switch the reduction ratio with an electromagnetic member such as a solenoid, and the operation of switching the reduction ratio is performed under control by a control circuit 13.

[0025] The control circuit 13 also controls the rotation of the motor 10 in response to an operation of a trigger switch 14. The control circuit 13 that drives the motor 10 via a motor driving circuit 15 is connected to a number-of-rotations detecting means 16 detecting the number N of rotations of the motor 10, and is connected to a current detecting means 17 detecting a motor driving current I. When the operation of switching the reduction ratio is performed automatically in response to a working load, the control circuit 13 commands the transmission 11 to switch the reduction ratio in response to a detection output of a driving state detecting means formed of both the detecting means 16 and 17.

[0026] When the output load is small at the start of the motor 10, the motor driving current I increases and the increase rate of the number N of rotations of the motor also increases. When the output load is large, the motor driving current I increases similarly, but the increase rate of the number N of rotations of the motor decreases or becomes zero.

[0027] Therefore, the control circuit 13 formed of a one-chip microcomputer in the electric tool starts the motor 10 in a state where the reduction ratio is set on the low side (reduction ratio 1 in Fig. 1) as the initial setting. When two conditions that the motor driving current $I \geq I1$ (A) and the increase rate of the number of rotations of the motor $\leq \alpha 1$ are satisfied, automatic gear shift to the high reduction ratio side (reduction ratio 2 in Fig. 1) is performed.

[0028] When work is performed where the load at the start is small and the working load gradually increases during continuation of the work, the motor driving current I gradually increases and the number N of rotations of the motor decreases. However, when the conditions that the motor driving current $I \geq I1$ (A) and the increase rate of the number N of rotations of the motor $\leq \alpha 1$ are satisfied, the control circuit 13 automatically shifts the transmission 11 to the high reduction ratio side. Reduction of the number N of rotations of the motor indicates that the increase rate is a negative value.

[0029] Since automatic gear shift is performed under the conditions, even when the worker repeats an operation of turning on trigger switch 14 and returning it to a near OFF state in the output no-load state (current of Fig. 8(b) flows), false automatic gear shift is not caused by a rush current when the value of $\alpha 1$ is set at a determinable increase rate.

[0030] In the case where the reduction ratio can be switched to a higher state (reduction ratio 3 in Fig. 1) (three speed gear), it is previously set that automatic gear shift to the higher reduction ratio state is performed when the two conditions that the motor driving current $I \geq I2$ (A) and the increase rate of the number N of rotations of the motor $\leq \alpha 2$ are satisfied. It is assumed that $I1 < I2$ and $\alpha 1 > \alpha 2$, but this assumption may be changed dependently on the setting of the reduction ratio to be switched.

[0031] When the load decreases during the work, gear shift in the direction of decreasing the reduction ratio is performed, reversely. As the working load decreases, the motor driving current I decreases and the number N of rotations of the motor increases. Therefore, the conditions that the motor driving current $I \leq I4$ (A) and the increase rate of the number N of rotations of the motor $\geq \alpha 4$ are satisfied, automatic gear shift to the low reduction ratio (high speed side) is performed. In the case where gear shift to a higher speed side is enabled, the conditions that the motor driving current $I \leq I3$ (A) and the increase rate of the number N of rotations of the motor $\geq \alpha 3$ are satisfied, automatic gear shift to the high speed side is performed. It is assumed that $I4 > I3$ and $\alpha 3 > \alpha 4$, but this assumption may be changed dependently on the setting of the reduction ratio to be switched.

[0032] Thus, the gear shift conditions include not only the motor driving current I but also the number N of rotations of the motor or the increase rate thereof. Therefore, the work can be performed at a reduction ratio appropriate for the working load, a false gear shift can be prevented, and a tool driving unit can be prevented from undergoing an excessive load.

[0033] In the present embodiment, the determination is performed based on the value of the increase rate of the number N of rotations of the motor. However, the value of the number N of rotations may be used as a determination condition. Especially, when gear shift to the low reduction ratio (high speed side) is performed, even if the increase rate is not used as the condition, there is no possibility of causing another problem. In the flowchart of Fig. 1, the value of the number N of rotations of the motor is used as a condition of the automatic gear shift to the low reduction ratio (high speed side). For automatic gear shift to the high reduction ratio (low speed side), however, it is preferable to use the increase rate of the number of rotations per unit time. This is because the effect of a rush current can be easily avoided.

[0034] When the temperature of the motor 10 increases, the N-T (the number of rotations - torque) characteristic varies (decreases) as shown in Fig. 3. Therefore, when the timing of the gear shift is determined based on a fixed motor current value I, the torque value during gear shift decreases gradually. In this case, the working speed also decreases gradually and the working efficiency extremely decreases.

[0035] In order to avoid this problem, as shown in Fig. 4, a motor driving temperature detecting means 19 is provided which detects the temperature of the motor 10 or the temperature of the motor driving circuit 15. The controlling circuit 13 corrects the condition value for switching of the reduction ratio in response to the motor driving temperature Tm detected by the motor driving temperature detecting means 19, thereby preventing reduction of the torque during gear shift and preventing reduction of the working speed.

[0036] An example is described where the above-mentioned correction is performed for the current value compared with the value of the motor current I, for example. A controlling means that can switch the reduction ratio between three stages and uses the I1, I2, I3, and I4 as the condition values for the motor current for gear shift is taken as an example. When the motor driving temperature Tm is lower than a preset temperature Tm1, current values I11, I21, I31, and I41 are used as the current values I1, I2, I3, and I4 for determination. When the motor driving temperature Tm is equal to or higher than the temperature Tm1 and is lower than a temperature Tm2, current values I12, I22, I32, and I42 are used. When the motor driving temperature Tm is the temperature Tm2 or higher and is lower than a temperature Tm3, current values I13, I23, I33, and I43 are used. Here, Tm3>Tm2>Tm1, I11<I12<I13, and I21<I22<I23, and the current value for reduction determination is set larger as the motor driving temperature Tm becomes higher. For gear shift to the low reduction ratio, I31<I32<I33 and I41<I42<I43 are assumed.

[0037] Fig. 5 shows a flowchart in this case. The correction is performed by setting a table, but the determination current value may be varied in response to the motor driving temperature based on a function expression of the motor driving temperature and the determination current. Preferably, when the motor driving temperature Tm is Tm3 or higher, the motor driving temperature Tm is determined as abnormal temperature, and the motor driving is forcibly stopped, thereby preventing damage of the tool.

[0038] When the work is performed continuously, not only the motor driving temperature Tm increases, but also a battery temperature Tb in the battery pack 18 as a power supply increases. When the battery is a lithium battery, it is not preferable that the temperature increases. Therefore, when the battery temperature Tb becomes high, the tool is forcibly stopped even if the work can be continued by increasing the reduction ratio. However, this operation significantly decreases the working efficiency.

[0039] Therefore, a battery temperature detecting means (power supply detecting means) 20 detecting the temperature of the battery is provided as shown in Fig. 6. The controlling circuit 13 corrects the condition value for switching of the reduction ratio in response to the value of the battery temperature Tb detected by the battery temperature detecting means 20. Thus, the load of the motor 10 is reduced and hence the increase in battery temperature Tb can be suppressed.

[0040] For example, when the detected battery temperature Tb is lower than a condition value Tb1, the determination current values I1 to I4 are not varied. When the battery temperature Tb is the condition value Tb1 or higher and is lower than a condition value Tb2, the determination current values I1 and I2 are corrected to small values, and gear shift to a high reduction ratio state is early performed. When the battery temperature Tb is the condition value Tb2 or higher, the motor 10 is forcibly stopped.

[0041] Thus, the increase in battery temperature can be restricted while the work is continued. Furthermore, a phenomenon can be prevented where the battery temperature Tb increases, the motor 10 suddenly stops, and the work is disabled. Therefore, the work can be continued safely.

[0042] The correction based on the battery temperature Tb can be also performed by setting a table, and the determination current values may be varied in response to the battery temperature Tb based on a function expression of the battery temperature Tb and the determination current.

[0043] In the flowchart shown in Fig. 7, the condition values (determination current values) are corrected based on the table in response to both the motor driving temperature Tm and the battery temperature Tb. Specifically, when the battery temperature Tb < Tb1, correction based on the battery temperature is not performed, and a correction value determined by the motor driving temperature Tm is used. However, when the battery temperature Tb satisfies the condition that Tb1≤Tb<Tb2, namely when the battery temperature Tb is high, the reduction ratio is switched using not the correction value determined by the motor driving temperature Tm but the correction value set in response to the battery temperature Tb. By automatic gear shift to the high reduction ratio (low speed side), the motor current value is reduced. Thus, the increase in battery temperature can be restricted. By reducing the speed while a high priority is put on the gear shift determination value based on the battery temperature, differently from the conventional art, the worker can safely continue the work without sudden stop and without disabling the work. Similarly to the above-mentioned embodiment, the motor 10 is forcibly stopped when the battery temperature Tb is Tb2 or higher and the battery generates heat. The increase in battery temperature does not immediately cause forced stop of the motor 10, so that the work can be safely continued.

[0044] When the condition values (determination current values) are corrected in response to both the motor driving temperature Tm and the battery temperature Tb, the following gear shift may be employed:

a determination current value after the correction based on the motor driving temperature Tm and a determination current value after the correction based on the battery temperature Tb are individually derived, and the gear shift is performed using the smaller one of the determination current values.

The load of both the motor 10 and the battery pack 18 can be reduced, and the work can be safely continued.

[0045] In each of the above-mentioned examples, the motor current I and the number N of rotations of the motor are used as the driving states that are to be detected for automatic switching of the reduction ratio. However, the motor current I and motor driving temperature Tm, the motor current I and battery temperature Tb, the motor driving temperature Tm and the number N of rotations of the motor, or the number N of rotations and battery temperature Tb may be used. The reduction ratio may be switched when three or more of the above-mentioned parameters satisfy the respective preset conditions. The operation amount (trigger amount) of the trigger switch 14 may be one of the driving states that are to be detected for automatic switching of the reduction ratio.

[0046] As discussed above, the electric tool includes the motor 10, output unit 12, and transmission 11. The motor 10 defines a rotational power source. The output unit 12 is rotatably driven by the motor 10. The transmission 11 is disposed between the motor 10 and output unit 12. The transmission 11 is configured to switch the reduction ratio.

[0047] When the motor 10 drives the output unit 12, the driving state of the motor 10 varies in response to the magnitude of the load charged on the motor 10.

[0048] The electric tool includes a driving state detecting means and a controlling means (control circuit 13). The driving state detecting means is configured to detect at least two driving states. The two driving states vary in response to the magnitude of the load when the output unit 12 is driven. The controlling means makes the transmission 11 switch the reduction ratio when the at least two driving states detected by the driving state detecting means satisfy predetermined conditions preset for the respective driving states.

[0049] In other words, the electric tool includes the driving state detecting means and the controlling means. The driving state detecting means is configured to detect the driving state of the motor 10. The driving state detecting means is configured to detect the at least two driving states. One of the at least two driving states is the first driving state, and the other is the second driving state. Thus, the driving state detecting means is configured to detect the first driving state and the second driving state. The first driving state is one of the driving states varying in response to the magnitude of the load when the output unit 12 is driven. The second driving state is a driving state varying in response to the magnitude of the load when the output unit 12 is driven. The second driving state is different from the first driving state. The controlling means is configured to recognize whether the first driving state satisfies the first condition. The controlling means is configured to recognize whether the second driving state satisfies the second condition. The controlling means is configured to make the transmission 11 switch the reduction ratio when the first driving state satisfies the first condition and the second driving state satisfies the second condition.

[0050] The controlling means uses, as a driving state to be compared with each predetermined condition, a driving state that differs between the operation of switching the reduction ratio from the low reduction ratio side to the high reduction ratio side and the operation of switching the reduction ratio from the high reduction ratio side to the low reduction ratio side.

[0051] In other words, the following driving states are different from each other:

the driving state that is compared with the predetermined condition when the controlling means performs the operation of switching the reduction ratio from the low reduction ratio side to the high reduction ratio side; and

the driving state that is compared with the predetermined condition when the controlling means performs the operation of switching the reduction ratio from the high reduction ratio side to the low reduction ratio side.

[0052] The at least two driving states detected by the driving state detecting means indicate the motor driving current value, and the number of rotations of the motor 10 or the increase rate of the number of rotations of the motor 10. In other words, the first driving state indicates the motor driving current value. The second driving state indicates the number of rotations of the motor 10 or the increase rate of the number of rotations of the motor 10.

[0053] The controlling means includes a number-of-rotations detecting means 16. The number-of-rotations detecting means 16 is configured to detect the number of rotations of the motor 10. The controlling means is configured to recognize the number of rotations of the motor 10 based on the number of rotations of the motor 10 detected by the number-of-rotations detecting means 16.

[0054] The controlling means may recognize the change rate of the number of rotations of the motor 10. In this case, the controlling means includes the number-of-rotations detecting means 16. The number-of-rotations detecting means 16 is configured to detect the number of rotations of the motor 10. The controlling means is configured to recognize the increase rate of the number of rotations of the motor 10 based on the variation of the number of rotations of the motor 10 detected by the number-of-rotations detecting means 16.

[0055] The electric tool includes a current detecting means 17. The current detecting means 17 is configured to detect a motor driving current for driving the motor 10.

The controlling means is configured to detect a motor driving current value based on the motor driving current detected by the current detecting means 17.

[0056] The controlling means makes the transmission 11 switch the reduction ratio from the low reduction ratio side to the high reduction ratio side when the motor driving current value and the increase rate of the number of rotations of the motor 10 satisfy respective predetermined conditions.

[0057] In other words, when the motor driving current value and the increase rate of the number of rotations of the motor 10 satisfy the respective predetermined conditions, the controlling means makes the transmission 11 switch the reduction ratio from a reduction ratio lower than a predetermined reduction ratio to a reduction ratio higher than the predetermined reduction ratio.

[0058] More specifically, when the motor driving current value is a first determination current value or higher and the increase rate of the number of rotations of the motor 10 is a first predetermined increase rate of the number of rotations or lower, the controlling means is configured to make the transmission 11 switch the reduction ratio from the low reduction ratio side to the high reduction ratio side.

[0059] In other words, when the motor driving current value is the first determination current value or higher and the increase rate of the number of rotations of the motor 10 is the first predetermined increase rate of the number of rotations or lower, the controlling means is configured to make the transmission 11 switch the reduction ratio from the reduction ratio lower than the predetermined reduction ratio to the reduction ratio higher than the predetermined reduction ratio.

[0060] In more detail, the controlling means is configured to make the transmission 11 switch the reduction ratio from the reduction ratio lower than the predetermined reduction ratio to the reduction ratio higher than the predetermined reduction ratio in the following condition:

> in the situation where the transmission is in the state of the reduction ratio lower than the predetermined reduction ratio, the motor driving current value is the first determination current value or higher and the increase rate of the number of rotations of the motor 10 is the first predetermined increase rate of the number of rotations or lower.

[0061] The first determination current value is a current value I1, for example. The first predetermined increase rate of the number of rotations is an increase rate $\alpha 1$, for example.

[0062] The controlling means operates the transmission 11 at a low reduction ratio when the motor 10 is started.

[0063] In other words, the controlling means operates the transmission 11 at a reduction ratio lower than the predetermined reduction ratio when the motor 10 is started.

[0064] The controlling means makes the transmission 11 switch the reduction ratio from a high reduction ratio side to a low reduction ratio side when the motor driving current value and the number of rotations of the motor 10 satisfy respective predetermined conditions.

[0065] In other words, when the motor driving current value and the number of rotations of the motor 10 satisfy the respective predetermined conditions, the controlling means makes the transmission 11 switch the reduction ratio from a reduction ratio higher than a predetermined reduction ratio to a reduction ratio lower than the predetermined reduction ratio.

[0066] More specifically, when the motor driving current value is a second determination current value or lower and the increase rate of the number of rotations of the motor 10 is a second predetermined number of rotations or higher, the controlling means is configured to make the transmission 11 switch the reduction ratio from the high reduction ratio side to the low reduction ratio side.

[0067] In other words, when the motor driving current value is the second determination current value or lower and the increase rate of the number of rotations of the motor 10 is the second predetermined number of rotations or higher, the controlling means is configured to make the transmission 11 switch the reduction ratio from the reduction ratio higher than the predetermined reduction ratio to the reduction ratio lower than the predetermined reduction ratio.

[0068] In more detail, the controlling means is configured to make the transmission 11 switch the reduction ratio from the reduction ratio higher than the predetermined reduction ratio to the reduction ratio lower than the predetermined reduction ratio in the following condition:

> in the situation where the transmission is in the state of a reduction ratio higher than the predetermined reduction ratio, the motor driving current value is the second determination current value or lower and the number of rotations of the motor 10 is the second predetermined number of rotations or higher.

[0069] The first determination current value may be different from the second determination current value.

[0070] When the motor driving current value is a second determination current value or lower and the increase rate of the number of rotations of the motor 10 is a second predetermined increase rate of the number of rotations or higher, the controlling means may be configured to make the transmission 11 switch the reduction ratio from a high reduction ratio side to a low reduction ratio side. The first predetermined increase rate of the number of rotations may be different from the second predetermined increase rate of the number of rotations.

[0071] In other words, when the motor driving current value is the second determination current value or lower and the increase rate of the number of rotations of the motor 10 is the second predetermined increase rate of the number of rotations or higher, the controlling means is configured to make the transmission 11 switch the reduction ratio from a reduction ratio higher than the predetermined reduction ratio to a reduction ratio lower than the predetermined reduction ratio. The first predetermined increase rate of the number of rotations may be different from the second predetermined increase rate of the number of rotations.

[0072] The electric tool may include a motor driving temperature detecting means 19, as shown in Fig. 4. The motor driving temperature detecting means is configured to detect the motor driving temperature. The motor driving temperature is the temperature of the motor or the temperature of the driving circuit of the motor. The controlling means corrects the predetermined condition for switching of the reduction ratio in response to the motor driving temperature detected by the motor driving temperature detecting means.

[0073] One of the driving states detected by the driving state detecting means is the motor driving current value. The controlling means increases the predetermined condition for the motor driving current value when the motor driving temperature detected by the motor driving temperature detecting means 19 is higher than a predetermined value.

[0074] The electric tool may include a power supply temperature detecting means, as shown in Fig. 6. The power supply temperature detecting means is configured to detect the temperature of the power supply. The controlling means is configured to correct the predetermined condition for switching of the reduction ratio in response to the power supply temperature detected by the power supply temperature detecting means.

[0075] In more detail, the electric tool includes the power supply temperature detecting means detecting the temperature of the power supply. The controlling means is configured to make the transmission 11 switch the reduction ratio from a low reduction ratio side to a high reduction ratio side when three conditions (a), (b), and (c) are satisfied. The condition (a) indicates that the power supply temperature detected by the power supply temperature detecting means is lower than a first condition temperature. The condition (b) indicates that the driving current value of the motor 10 is a first determination current value or higher. The condition (c) indicates that the increase rate of the number of rotations of the motor 10 is the first predetermined increase rate of the number of rotations or lower.

[0076] The controlling means is configured to make the transmission 11 switch the reduction ratio from the low reduction ratio side to the high reduction ratio side when three conditions (d), (e), and (f) are satisfied. The condition (d) indicates that the power supply temperature detected by the power supply temperature detecting means is the first condition temperature or higher and is lower than a second condition temperature. The condition (e) indicates that the motor driving current value is a first correction current value or higher. Here, the first correction current value is lower than the first determination current value. The condition (f) indicates that the increase rate of the number of rotations of the motor 10 is the first predetermined increase rate of the number of rotations or lower.

[0077] The controlling means forcibly stops the motor 10 when the power supply temperature detected by the power supply temperature detecting means is a second condition temperature or higher.

[0078] One of the driving states detected by the driving state detecting means is the motor driving current value. The controlling means decreases the predetermined condition for the motor driving current value when the power supply temperature detected by the power supply temperature detecting means is higher than a predetermined value.

[0079] The motor driving temperature detecting means 19 and the power supply temperature detecting means may be combined with each other. In other words, the electric tool includes the motor driving temperature detecting means 19 and the power supply temperature detecting means. The motor driving temperature detecting means 19 is configured to detect the temperature of the motor 10. Alternatively, the motor driving temperature detecting means 19 is configured to detect the temperature of the motor driving circuit 15 for the motor 10. The power supply temperature detecting means is configured to detect the temperature of the power supply.

[0080] The controlling means is configured to correct the predetermined conditions in response to the motor driving temperature detected by the motor driving temperature detecting means 19 and the power supply temperature detected by the power supply temperature detecting means. When the power supply temperature is high, the controlling means puts a higher priority on the correction of the predetermined condition based on the power supply temperature than on the correction of the predetermined condition based on the motor driving temperature.

[0081] In other words, the controlling means is configured to correct the predetermined conditions in response to the motor driving temperature detected by the motor driving temperature detecting means 19 and the power supply temperature detected by the power supply temperature detecting means. When the power supply temperature is higher than a predetermined temperature, the controlling means does not correct the predetermined condition based on the motor driving temperature, but corrects the predetermined condition based on the power supply temperature.

[0082] The controlling means may employ the smaller one of the following correction values:

the correction value of the predetermined condition for the motor driving current value when the motor driving temperature detected by the motor driving temperature detecting means 19 is higher than a pre-

determined value; and
the correction value of the predetermined condition for the motor driving current value when the power supply temperature detected by the power supply temperature detecting means is higher than a predetermined value.

DESCRIPTION OF THE REFERENCE NUMERALS

[0083]

10	Motor
11	Transmission
12	Output unit
13	Control circuit
14	Trigger switch
15	Motor driving circuit
16	Motor number-of-rotations detecting means
17	Motor current detecting means
18	Battery pack
19	Motor driving temperature detecting means
20	Battery temperature detecting means

Claims

1. An electric tool including a transmission (11) for switching a reduction ratio, the transmission (11) being disposed between a motor (10) as a rotational power source and an output unit (12) rotatably driven by the motor (10), the electric tool comprising:

    a driving state detecting means detecting at least two driving states of driving states which vary in response to a magnitude of a load when the output unit (12) is driven; and
    a controlling means making the transmission (11) switch the reduction ratio when the at least two driving states detected by the driving state detecting means satisfy predetermined conditions preset for the at least two driving states, respectively.

2. The electric tool according to claim 1, wherein
the controlling means employs, as a driving state to be compared with each predetermined condition, a driving state which differs between an operation of switching the reduction ratio from a low reduction ratio side to a high reduction ratio side and an operation of switching the reduction ratio from a high reduction ratio side to a low reduction ratio side.

3. The electric tool according to claim 1 or 2, wherein
the at least two driving states detected by the driving state detecting means indicate a motor driving current value, and the number of rotations of the motor or an increase rate of the number of rotations of the motor.

4. The electric tool according to one of claims 1 to 3, wherein
the controlling means switches the reduction ratio from a low reduction ratio side to a high reduction ratio side when a motor driving current value and an increase rate of the number of rotations of the motor satisfy the respective predetermined conditions.

5. The electric tool according to one of claims 1 to 3, wherein
the controlling means switches the reduction ratio from a high reduction ratio side to a low reduction ratio side when a motor driving current value and the number of rotations of the motor satisfy the respective predetermined conditions.

6. The electric tool according to one of claims 1 to 5, further comprising a motor driving temperature detecting means (19) detecting a temperature of the motor (10) or a motor driving circuit (15) for the motor (10),
wherein the controlling means corrects the predetermined conditions for switching of the reduction ratio in response to a motor driving temperature detected by the motor driving temperature detecting means (19).

7. The electric tool according to claim 6, wherein
one of the driving states detected by the driving state detecting means indicates a motor driving current value, and
the controlling means increases a predetermined condition for the motor driving current value when a value of the motor driving temperature detected by the motor driving temperature detecting means (19) is higher than a predetermined value.

8. The electric tool according to one of claims 1 to 5, further comprising a power supply temperature detecting means detecting a temperature of a power supply,
wherein the controlling means corrects the predetermined conditions for switching of the reduction ratio in response to the power supply temperature detected by the power supply temperature detecting means.

9. The electric tool according to claim 8, wherein
one of the driving states detected by the driving state detecting means indicates a motor driving current value, and
the controlling means decreases a predetermined condition for the motor driving current value when the power supply temperature detected by the power supply temperature detecting means is higher than a predetermined value.

10. The electric tool according to one of claims 1 to 5,

further comprising:

a motor driving temperature detecting means (19) detecting a temperature of the motor (10) or a motor driving circuit (15) for the motor (10); and
a power supply temperature detecting means detecting a temperature of a power supply, wherein
the controlling means corrects the predetermined conditions in response to a motor driving temperature detected by the motor driving temperature detecting means (19) and a power supply temperature detected by the power supply temperature detecting means, and
when the power supply temperature is high, the controlling means puts a higher priority on correction of the predetermined condition based on the power supply temperature than on correction of the predetermined condition based on the motor driving temperature.

11. The electric tool according to one of claims 1 to 5, further comprising:

a motor driving temperature detecting means (19) detecting a temperature of the motor (10) or a motor driving circuit (15) for the motor (10); and
a power supply temperature detecting means detecting a temperature of a power supply, wherein
one of the driving states detected by the driving state detecting means indicates a motor driving current value,
the controlling means employs a smaller correction value of:

a correction value of a predetermined condition for the motor driving current value when the motor driving temperature detected by the motor driving temperature detecting means (19) is higher than a predetermined value; and
a correction value of a predetermined condition for the motor driving current value when the power supply temperature detected by the power supply temperature detecting means is higher than a predetermined value.

FIG. 1

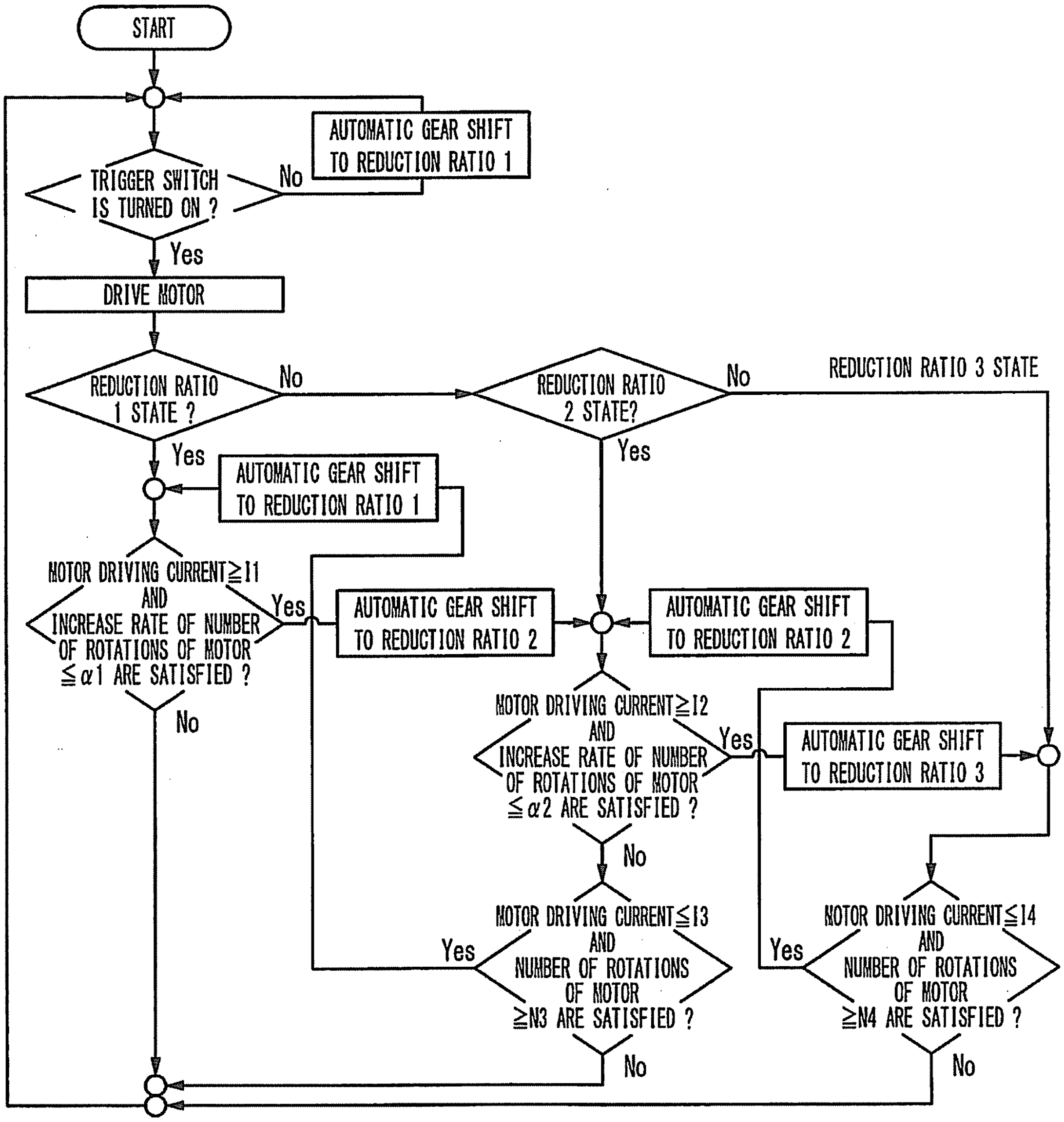

START
TRIGGER SWITCH IS TURNED ON ?
No
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 1
Yes
DRIVE MOTOR
REDUCTION RATIO 1 STATE ?
No
REDUCTION RATIO 2 STATE?
No
REDUCTION RATIO 3 STATE
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 1
Yes
MOTOR DRIVING CURRENT≧I1 AND INCREASE RATE OF NUMBER OF ROTATIONS OF MOTOR ≦α1 ARE SATISFIED ?
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 2
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 2
No
MOTOR DRIVING CURRENT≧I2 AND INCREASE RATE OF NUMBER OF ROTATIONS OF MOTOR ≦α2 ARE SATISFIED ?
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 3
No
MOTOR DRIVING CURRENT≦I3 AND NUMBER OF ROTATIONS OF MOTOR ≧N3 ARE SATISFIED ?
Yes
No
MOTOR DRIVING CURRENT≦I4 AND NUMBER OF ROTATIONS OF MOTOR ≧N4 ARE SATISFIED ?
Yes
No

FIG. 2

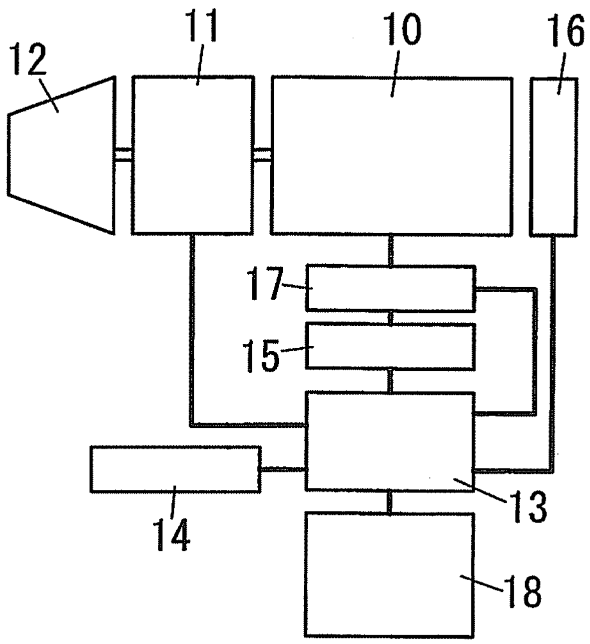

12
11
10
16
17
15
13
14
18

FIG. 3

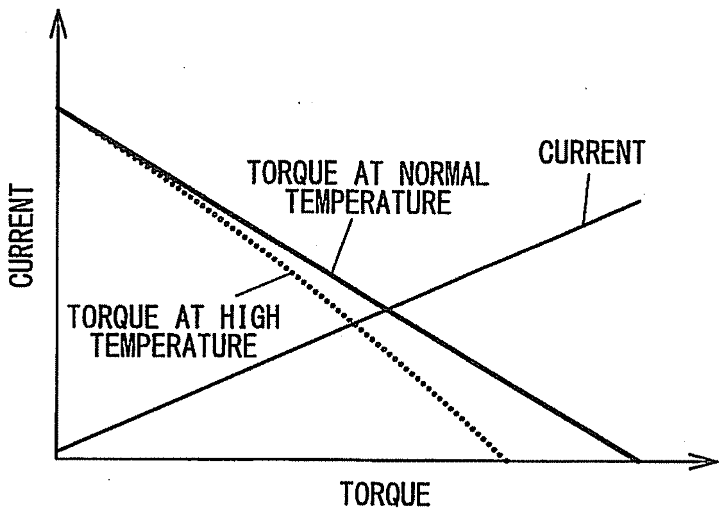

CURRENT
TORQUE AT NORMAL TEMPERATURE
CURRENT
TORQUE AT HIGH TEMPERATURE
TORQUE

FIG. 4

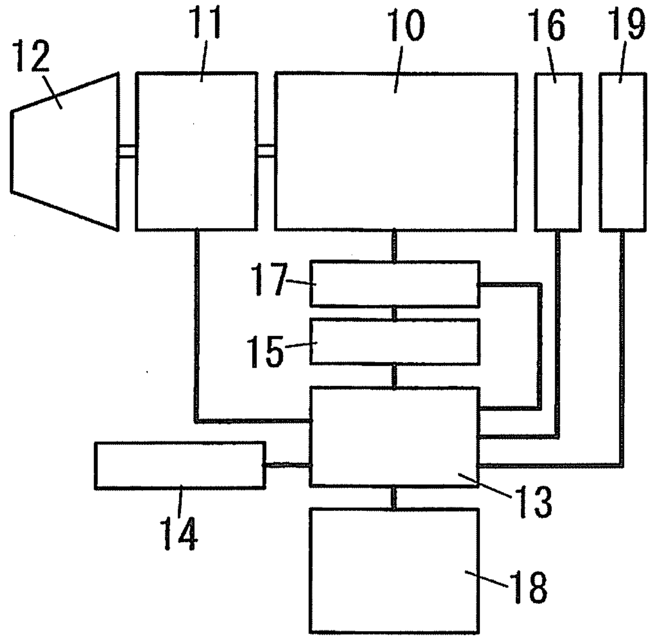


FIG. 5

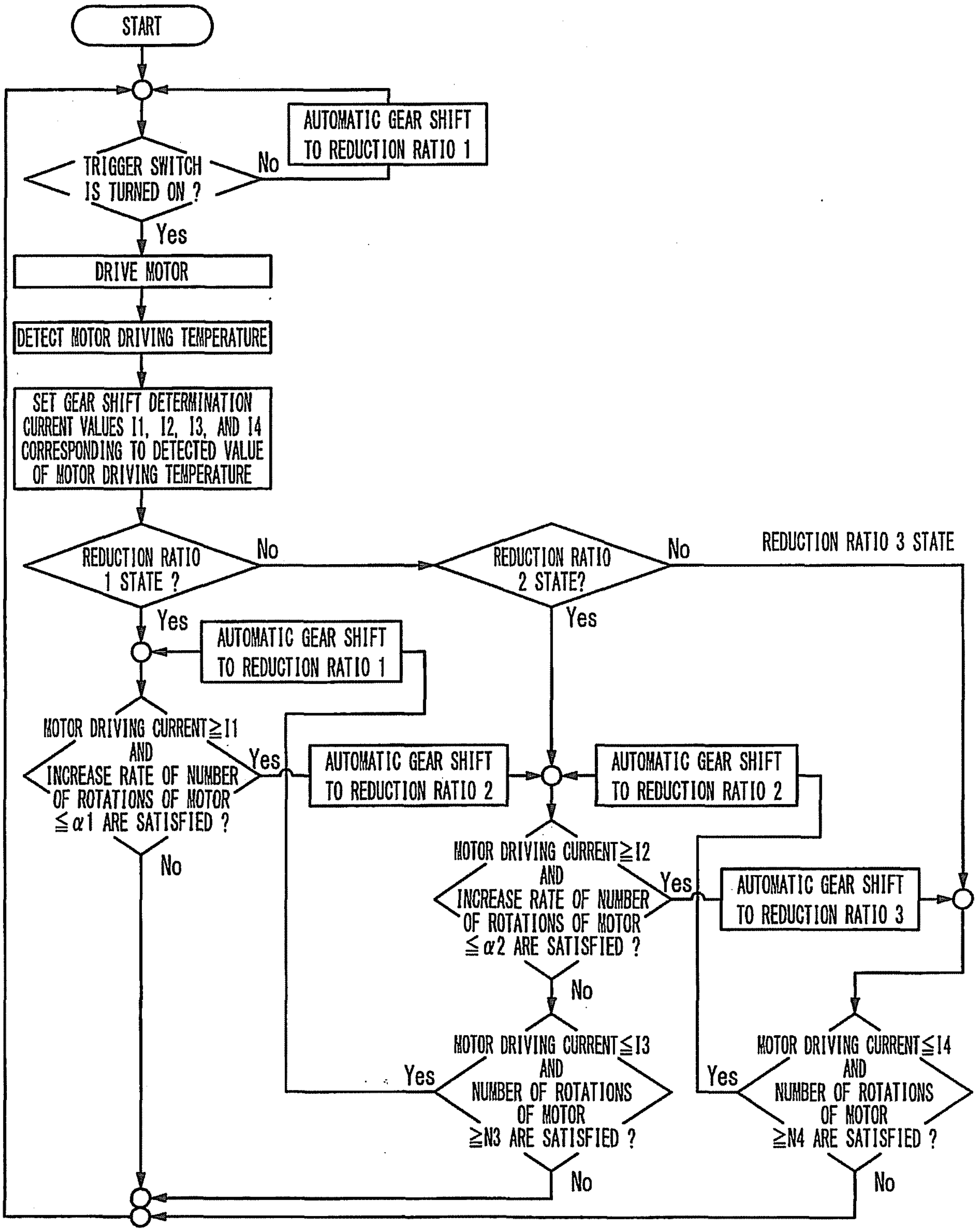

START
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 1
TRIGGER SWITCH IS TURNED ON ?
No
Yes
DRIVE MOTOR
DETECT MOTOR DRIVING TEMPERATURE
SET GEAR SHIFT DETERMINATION CURRENT VALUES I1, I2, I3, AND I4 CORRESPONDING TO DETECTED VALUE OF MOTOR DRIVING TEMPERATURE
REDUCTION RATIO 1 STATE ?
No
REDUCTION RATIO 2 STATE?
No
REDUCTION RATIO 3 STATE
Yes
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 1
MOTOR DRIVING CURRENT≧I1 AND INCREASE RATE OF NUMBER OF ROTATIONS OF MOTOR ≦α1 ARE SATISFIED ?
Yes
No
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 2
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 2
MOTOR DRIVING CURRENT≧I2 AND INCREASE RATE OF NUMBER OF ROTATIONS OF MOTOR ≦α2 ARE SATISFIED ?
Yes
No
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 3
MOTOR DRIVING CURRENT≦I3 AND NUMBER OF ROTATIONS OF MOTOR ≧N3 ARE SATISFIED ?
Yes
No
MOTOR DRIVING CURRENT≦I4 AND NUMBER OF ROTATIONS OF MOTOR ≧N4 ARE SATISFIED ?
Yes
No

FIG. 6

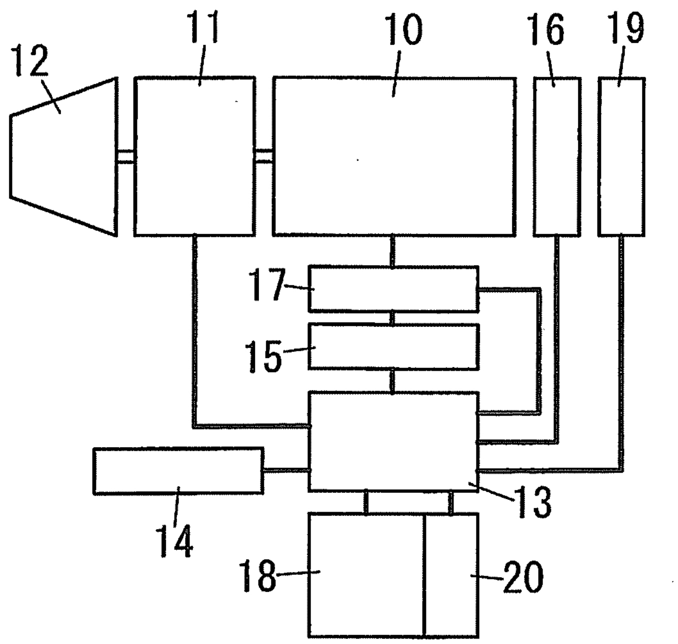


FIG. 7

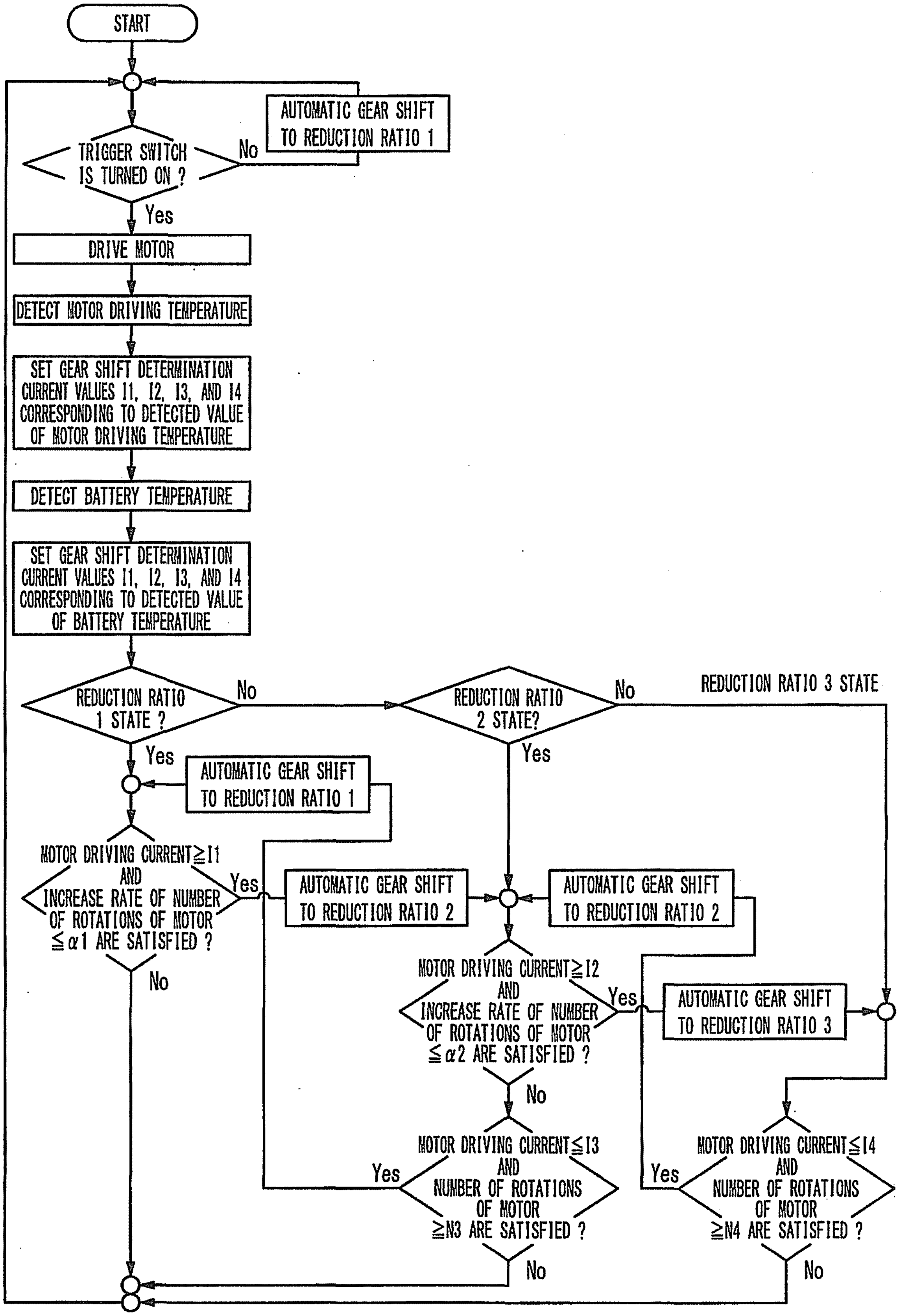
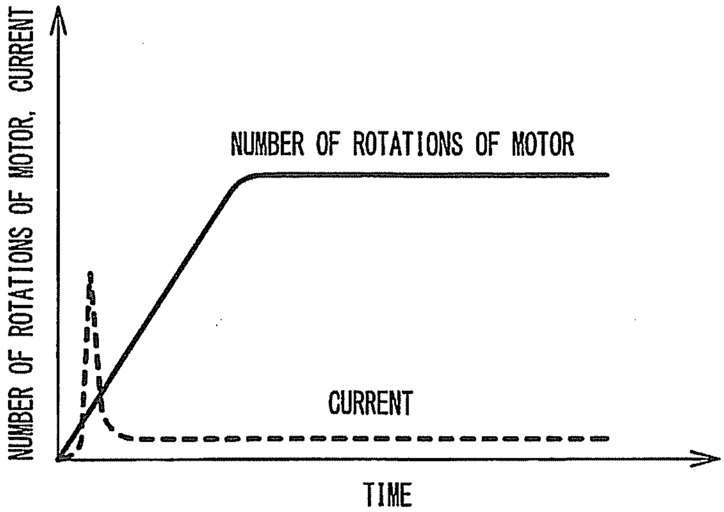
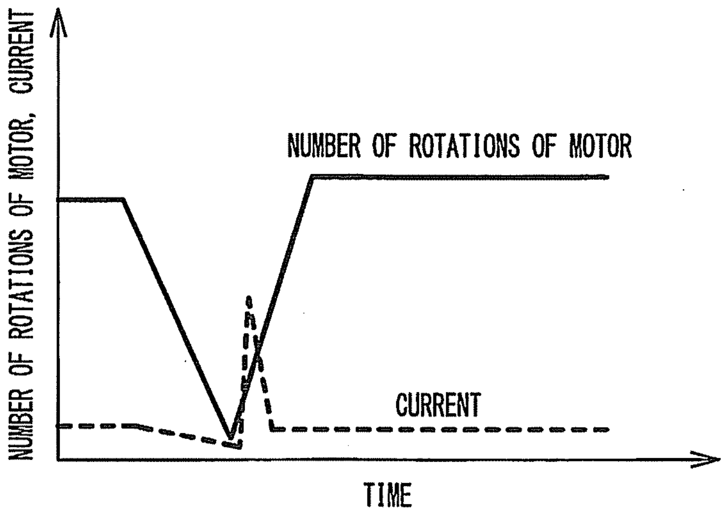

START
TRIGGER SWITCH IS TURNED ON ?
No
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 1
Yes
DRIVE MOTOR
DETECT MOTOR DRIVING TEMPERATURE
SET GEAR SHIFT DETERMINATION CURRENT VALUES I1, I2, I3, AND I4 CORRESPONDING TO DETECTED VALUE OF MOTOR DRIVING TEMPERATURE
DETECT BATTERY TEMPERATURE
SET GEAR SHIFT DETERMINATION CURRENT VALUES I1, I2, I3, AND I4 CORRESPONDING TO DETECTED VALUE OF BATTERY TEMPERATURE
REDUCTION RATIO 1 STATE ?
No
REDUCTION RATIO 2 STATE?
No
REDUCTION RATIO 3 STATE
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 1
Yes
MOTOR DRIVING CURRENT≧I1 AND INCREASE RATE OF NUMBER OF ROTATIONS OF MOTOR ≦α1 ARE SATISFIED ?
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 2
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 2
No
MOTOR DRIVING CURRENT≧I2 AND INCREASE RATE OF NUMBER OF ROTATIONS OF MOTOR ≦α2 ARE SATISFIED ?
Yes
AUTOMATIC GEAR SHIFT TO REDUCTION RATIO 3
No
MOTOR DRIVING CURRENT≦I3 AND NUMBER OF ROTATIONS OF MOTOR ≧N3 ARE SATISFIED ?
Yes
No
MOTOR DRIVING CURRENT≦I4 AND NUMBER OF ROTATIONS OF MOTOR ≧N4 ARE SATISFIED ?
Yes
No

FIG. 8

(a)


NUMBER OF ROTATIONS OF MOTOR, CURRENT
NUMBER OF ROTATIONS OF MOTOR
CURRENT
TIME

(b)


NUMBER OF ROTATIONS OF MOTOR, CURRENT
NUMBER OF ROTATIONS OF MOTOR
CURRENT
TIME

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/052595

A. CLASSIFICATION OF SUBJECT MATTER
B25F5/00(2006.01)i, *B25B23/14*(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)
B25F3/00-5/02, B25B23/00-23/18, B25B21/00-21/02, B23B45/00-45/16

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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.
A	JP 2009-56590 A (Positec Power Tools (Suzhou) Co., Ltd.), 19 March 2009 (19.03.2009), & US 2009/0071671 A1 & US 2009/0071673 A1 & US 2011/0162861 A1 & EP 2030709 A2 & EP 2030710 A2 & CN 101377229 A & CN 101637906 A	1-11
A	JP 9-183076 A (Shibaura Engineering Works Co., Ltd.), 15 July 1997 (15.07.1997), (Family: none)	1-11
A	JP 8-68446 A (Matsushita Electric Works, Ltd.), 12 March 1996 (12.03.1996), & US 5711739 A & DE 19531043 A1	1-11

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

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 22 February, 2012 (22.02.12)	Date of mailing of the international search report 06 March, 2012 (06.03.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/052595

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/134431 A1 (Makita Corp.), 25 November 2010 (25.11.2010), & JP 2010-264578 A	1-11
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 136690/1985(Laid-open No. 46570/1987) (Alps Electric Co., Ltd.), 20 March 1987 (20.03.1987), (Family: none)	1-11
A	JP 7-124827 A (Matsushita Electric Industrial Co., Ltd.), 16 May 1995 (16.05.1995), (Family: none)	1-11
A	EP 0808018 A1 (Black & Decker Inc.), 19 November 1997 (19.11.1997), & DE 69631754 T2	1-11

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009078349 A **[0008]**
- JP 2009056590 A **[0008]**