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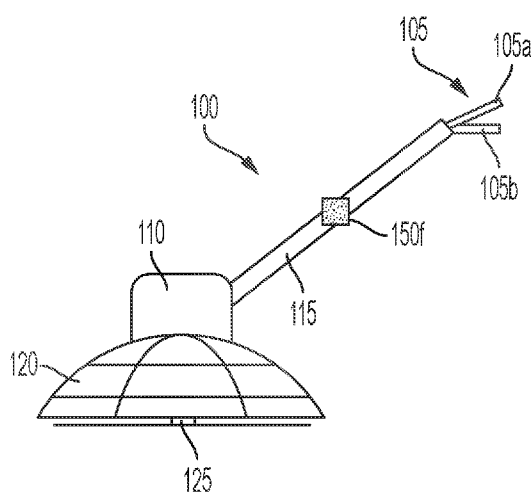


FIG. 4B

(57) Abstract: Systems and methods for controlling a power trowel. A power trowel includes a handle, a housing, a blade assembly, a motor coupled to the blade assembly, a motion sensor, and a controller. The motion sensor is configured to provide an output signal indicative of motion of the power trowel. The output signal includes an orientation signal indicative of an orientation of the power trowel. The controller is connected to the motor and the motion sensor. The controller is configured to receive the output signal from the motion sensor, determine, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold, and deactivate the motor in response to the angle of the power trowel being greater than or equal to the orientation threshold.

ANTI-KICKBACK CONTROL FOR BATTERY PACK POWERED TROWELS

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/284,828, filed December 1, 2021, the entire content of which is hereby incorporated by reference.

SUMMARY

[0002] Embodiments described herein provide systems and methods for determining and reacting to a kickback event or an otherwise uncontrolled state of a battery pack powered trowel. For example, a power trowel may begin to spin rapidly or be generally uncontrolled by an operator. In such an event, proposed systems and methods assist an operator in regaining control of the power trowel.

[0003] Power trowels described herein include a handle, a housing, a blade assembly, a motor coupled to the blade assembly, a motion sensor, and a controller. The motion sensor is configured to provide an output signal indicative of a motion of the power trowel. The output signal includes an orientation signal indicative of an orientation of the power trowel. The controller is connected to the motor and the motion sensor. The controller is configured to receive the orientation signal from the motion sensor, determine, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold, and deactivate the motor in response to the orientation of the power trowel being greater than or equal to the orientation threshold.

[0004] In some aspects, the output signal includes a velocity signal indicative of a velocity of motion of the power trowel. The controller is further configured to determine whether the velocity signal is greater than or equal to a velocity threshold, and deactivate the motor in response to the velocity signal being greater than or equal to the velocity threshold.

[0005] In some aspects, the motion sensor is located on the handle.

[0006] In some aspects, the orientation of the power trowel is an angle of the handle.

[0007] In some aspects, the motion sensor is located on the housing.

[0008] In some aspects, the power trowel further includes a battery pack connected to the motor, and a switch connected to the controller, the battery pack, and the motor. The controller is further configured to operate, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, the switch to disconnect the battery pack from the motor.

[0009] In some aspects, the power trowel further includes a load sensor configured to provide a load signal indicative of a load condition of the motor. The controller is further configured to monitor the load condition of the motor, and deactivate the motor in response to the load condition of the motor being outside a predetermined load operating range.

[0010] In some aspects, the load condition is at least one selected from the group consisting of a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.

[0011] Power trowels described herein include a handle, a housing, a blade assembly, a motor coupled to the blade assembly, a detector for detecting whether an operator is holding the handle, and a controller. The controller is connected to the motor and the detector. The controller is configured to operate the motor to drive the blade assembly, determine whether the operator is holding the handle, and deactivate the motor in response to determining the operator is not holding the handle.

[0012] In some aspects, the detector is a lever operable to be actuated by the operator. The controller is further configured to determine the operator is holding the handle when the lever is actuated, and determine the operator is not holding the handle when the lever is not actuated.

[0013] In some aspects, the power trowel further includes a battery pack configured to provide power to the motor. The controller is further configured to disconnect, in response to determining the operator is not holding the handle, the battery pack from the motor.

[0014] In some aspects, the detector is a tether configured to be connected to the power trowel. The controller is further configured to determine whether the tether is connected to the power trowel, and deactivate the motor in response to determining the tether is not connected to the power trowel.

[0015] In some aspects, the power trowel further includes a switch configured to deactivate, in response to being actuated, the motor.

[0016] In some aspects, the detector is a metal conductor integrated into the handle. The controller is further configured to monitor a resistance of the metal conductor, and deactivate the motor in response to detecting a change in the resistance of the metal conductor.

[0017] Power trowels described herein include a handle, a housing, a blade assembly, a motor coupled to the blade assembly, a battery pack configured to provide power to the motor, a motion sensor, and a controller. The motion sensor is configured to provide an output signal indicative of a motion of the power trowel. The output signal includes an orientation signal indicative of an orientation of the power trowel. The controller is connected to the motor and the motion sensor. The controller is configured to receive the output signal from the motion sensor, determine, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold, and decrease, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, an amount of power provided by the battery pack to the motor.

[0018] In some aspects, the amount of power provided by the battery pack to the motor is decreased to a non-zero value.

[0019] In some aspects, the output signal includes a velocity signal indicative of a velocity of a motion of the power trowel. The controller is further configured to determine whether the velocity signal is greater than or equal to a velocity threshold, and decrease, in response to the velocity signal being greater than or equal to the velocity threshold, the amount of power provided by the battery pack to the motor.

[0020] In some aspects, the motion sensor is located on the handle.

[0021] In some aspects, the power trowel further includes a load sensor configured to provide a load signal indicative of a load condition of the motor. The controller is further configured to monitor the load condition of the motor, and decrease, in response to the load condition of the motor being outside a predetermined load operating range, the amount of power provided by the battery pack to the motor.

[0022] In some aspects, the load condition is at least one selected from the group consisting of a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.

[0023] Methods of operating a power trowel described herein include operating a motor coupled to a blade assembly to drive the blade assembly and receiving an orientation signal from a motion sensor. The orientation signal is indicative of an orientation of the power trowel. The method includes determining, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold and deactivating the motor in response to the orientation of the power trowel being greater than or equal to the orientation threshold.

[0024] In some aspects, the method further includes providing, from the motion sensor, an output signal indicative of a motion of the power trowel. The output signal includes the orientation signal. The output signal includes a velocity signal indicative of a velocity of motion of the power trowel. The method also includes determining whether the velocity signal is greater than or equal to a velocity threshold, and deactivating the motor in response to the velocity signal being greater than or equal to the velocity threshold.

[0025] In some aspects, the motion sensor is located on a handle of the power trowel.

[0026] In some aspects, the orientation of the power trowel is an angle of the handle.

[0027] In some aspects, the motion sensor is located on a housing of the power trowel.

[0028] In some aspects, the method further includes operating, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, a switch to disconnect a battery pack from the motor.

[0029] In some aspects, the method further includes monitoring, based on a load signal received from a load sensor, a load condition of the motor, and deactivating the motor in response to the load condition of the motor being outside a predetermined load operating range.

[0030] In some aspects, the load condition is at least one selected from the group consisting of: a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.

[0031] Methods of operating a power trowel described herein include operating a motor coupled to a blade assembly to drive the blade assembly, determining, via a detector device whether an operator is holding a handle of the power trowel, and deactivating the motor in response to determining the operator is not holding the handle.

[0032] In some aspects, the detector device is a lever operable to be actuated by the operator, and the method includes determining the operator is holding the handle when the lever is actuated, and determining the operator is not holding the handle when the lever is not actuated.

[0033] In some aspects, the method includes disconnecting, in response to determining the operator is not holding the handle, a battery pack from the motor.

[0034] In some aspects, the detector device is a tether configured to be connected to the power trowel, and the method includes determining whether the tether is connected to the power trowel, and deactivating the motor in response to determining the tether is not connected to the power trowel.

[0035] In some aspects, the method includes deactivating the motor in response to a switch being actuated.

[0036] In some aspects, the detector device is a metal conductor integrated into the handle, and the method further includes monitoring a resistance of the metal conductor, and deactivating the motor in response to detecting a change in the resistance of the metal conductor.

[0037] Methods of operating a power trowel described herein include operating a motor coupled to a blade assembly to drive the blade assembly and receiving an orientation signal from a motion sensor. The orientation signal is indicative of an orientation of the power trowel. The method includes determining, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold, and decreasing, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, an amount of power provided by a battery pack to the motor.

[0038] In some aspects, the amount of power provided by the battery pack to the motor is decreased to a non-zero value.

[0039] In some aspects, the method further includes providing, from the motion sensor, an output signal indicative of a motion of the power trowel. The output signal includes the

orientation signal. The output signal includes a velocity signal indicative of a velocity of motion of the power trowel. The method includes determining whether the velocity signal is greater than or equal to a velocity threshold, and decreasing, in response to the velocity signal being greater than or equal to the velocity threshold, the amount of power provided by the battery pack to the motor.

[0040] In some aspects, the motion sensor is located on a handle of the power trowel.

[0041] In some aspects, the method includes monitoring, based on a load signal received from a load sensor, a load condition of the motor, and decreasing, in response to the load condition of the motor being outside a predetermined load operating range, the amount of power provided by the battery pack to the motor.

[0042] In some aspects, the load condition is at least one selected from the group consisting of a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.

[0043] Before any embodiments are explained in detail, it is to be understood that the embodiments are not limited in application to the details of the configuration and arrangement of components set forth in the following description or illustrated in the accompanying drawings. The embodiments are capable of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof are meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings.

[0044] In addition, it should be understood that embodiments may include hardware, software, and electronic components or modules that, for purposes of discussion, may be illustrated and described as if the majority of the components were implemented solely in hardware. However, one of ordinary skill in the art, and based on a reading of this detailed description, would recognize that, in at least one embodiments, the electronic-based aspects may be implemented in software (e.g., stored on non-transitory computer-readable medium) executable by one or more processing units, such as a microprocessor and/or application specific

integrated circuits (“ASICs”). As such, it should be noted that a plurality of hardware and software based devices, as well as a plurality of different structural components, may be utilized to implement the embodiments. For example, “servers” and “computing devices” described in the specification can include one or more processing units, one or more computer-readable medium modules, one or more input/output interfaces, and various connections (e.g., a system bus) connecting the components.

[0045] Other features and aspects will become apparent by consideration of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] FIG. 1 illustrates a side view of a power trowel in accordance with embodiments described herein.

[0047] FIG. 2 illustrates a front view of a power trowel in accordance with embodiments described herein.

[0048] FIG. 3 illustrates a side view of a power trowel having a tether in accordance with embodiments described herein.

[0049] FIG. 4A illustrates a front view of a power trowel having a kill switch in accordance with embodiments described herein.

[0050] FIG. 4B illustrates a side view of a power trowel having a kill switch in accordance with embodiments described herein.

[0051] FIG. 5 illustrates a front view of a power trowel having a charged handle in accordance with embodiments described herein.

[0052] FIG. 6 illustrates a block diagram of a controller for the power trowel of FIGS. 1-5 in accordance with embodiments described herein.

[0053] FIG. 7 illustrates a block diagram of a method of initiating protective operations performed by the controller of FIG. 6 in accordance with embodiments described herein.

[0054] FIG. 8 illustrates a block diagram of another method of initiating protective operations performed by the controller of FIG. 6 in accordance with embodiments described herein.

[0055] FIG. 9 illustrates a block diagram of another method of initiating protective operations performed by the controller of FIG. 6 in accordance with embodiments described herein.

[0056] FIG. 10 illustrates a block diagram of another method of initiating protective operations performed by the controller of FIG. 6 in accordance with embodiments described herein.

DETAILED DESCRIPTION

[0057] FIG. 1 illustrates an example of a battery pack powered or power trowel 100, according to some embodiments. The power trowel 100 includes a handle 105, a housing 110 (e.g., a motor housing), a shaft 115, a blade housing (or blade barrier) 120, and a blade assembly 125. The handle 105 is coupled to the housing 110 via the shaft 115. The handle 105 is composed of a first handle (or right handle) 105a and a second handle (or left handle) 105b. The housing 110 houses a motor 680 (shown in FIG. 6). The motor 680 drives the blade assembly 125. The blade housing 120 surrounds the blade assembly 125 to protect an operator or bystander from movement of the blade assembly 125.

[0058] The motor 680 may receive power from a battery pack 665 (shown in FIG. 6) coupled to the power trowel 100. For example, the battery pack 665 provides direct current (DC) power to the motor 680. However, the power trowel 100 may be configured to be operated by other types of power, such as, but not limited to, alternating-current (AC) power from an AC power source. In some embodiments, the power trowel 100 includes a power cable (e.g., a power cord). In other embodiments, the motor 680 is a gas-powered engine, and other electrical components of the power trowel 100 receive power, directly or indirectly, from AC or DC power generated by the gas-powered engine. Such electrical components may include, for example, kill switch 150a-150f, controller 600, indicators 645, load sensor 685, motion sensor 130a-130d, secondary sensors 690, tether detector 145, handle resistance module 695, and other components illustrated in FIG. 6.

[0059] In some embodiments, the power trowel 100 includes a motion sensor 130 (such as, for example, an accelerometer, a gyroscope, an angle sensor, or the like). The motion sensor 130 outputs signals indicative of detected motion of the power trowel 100. In some embodiments, as illustrated in FIG. 1, the motion sensor 130 is situated or located on the shaft 115. In some

embodiments, the motion sensor 130 may be located elsewhere on the power trowel 100. For example, as illustrated in FIG. 2, the power trowel 100 may include a motion sensor 130a situated on the handle 105. The motion sensor 130a may be located on either the first handle 105a or the second handle 105b. In other embodiments, the power trowel 100 may include a motion sensor 130b situated on the housing 110. The motion sensor 130b may be situated at a location where the shaft 115 couples to the housing 110 or generally on an upper portion of the housing 110. In some embodiments, the power trowel 100 includes a motion sensor 130c situated on a lower portion of the housing 110. For example, the motion sensor 130c may be situated at a location where the housing 110 couples to the blade housing 120. The motion sensor 130c may alternatively be situated on an upper portion of the blade housing 120. In some embodiments, the power trowel 100 includes a motion sensor 130d situated on a lower portion of the blade housing 120. While several locations of the motion sensor 130 are provided, the power trowel 100 may include a number of combinations of the motion sensors 130. As one non-limiting example, the power trowel 100 may include both the motion sensor 130a and the motion sensor 130c.

[0060] In some embodiments, as shown in FIG. 3, the power trowel 100 includes a tether 140. A first end of the tether 140 selectively couples to the power trowel 100. A second end of the tether 140 selectively couples to an operator 300 of the power trowel 100. While illustrated as coupling to the handle 105, in other embodiments, the tether 140 couples to the shaft 115, the housing 110, or the blade housing 120. The power trowel 100 may include a tether detector 145 for detecting whether the tether 140 is coupled to the power trowel 100. For example, should a distance between the power trowel 100 and the operator 300 exceed the length of the tether 140, the tether 140 disconnects from the power trowel 100.

[0061] In some embodiments, as shown in FIGS. 4A-4B, the power trowel 100 includes a kill switch 150a-150f. The kill switch 150a-150f is configured to shut off or reduce power to the motor 680 in response to being actuated. In some embodiments, the power trowel 100 includes a kill switch 150a situated on the first handle 105a. The power trowel 100 may include a kill switch 150b situated on the second handle 105b. In some embodiments, a kill switch 150c is situated at a location where the shaft 115 couples to the housing 110 or generally on an upper portion of the housing 110. In some embodiments, the power trowel 100 includes a kill switch 150d situated on a lower portion of the housing 110. For example, the kill switch 150d may be

situated at a location where the housing 110 couples to the blade housing 120. The kill switch 150d may alternatively be situated on an upper portion of the blade housing 120. In some embodiments, the power trowel 100 includes a kill switch 150e situated on a lower portion of the blade housing 120. In some embodiments, the power trowel 100 includes a kill switch 150f situated on the shaft 115. While several locations of the kill switch 150a-150f are provided, the power trowel 100 may include a number of combinations of the kill switch 150a-150f. As one non-limiting example, the power trowel 100 may include both the kill switch 150a and the kill switch 150c.

[0062] In some embodiments, as shown in FIG. 4A, the power trowel 100 includes a switch or lever (e.g., a trigger) 108 configured to be actuated while the motor 680 is running. For example, an operator holds the lever while operating the power trowel 100. Should the operator release the lever, the motor 680 will shut off.

[0063] In some embodiments, the handle 105 is charged with a low electrical voltage or current, as shown in FIG. 5. In such embodiments, the handle 105 may be constructed of a metallic material or include a metal conductor (e.g., sheet) which is provided with the low electrical current. In some embodiments, the metal conductor is integrated into the handle 105. The corresponding resistance of the handle 105 experiences a change when an operator places their hands on the handle 105.

[0064] A controller 600 for the power trowel 100 is illustrated in FIG. 6. The controller 600 is electrically and/or communicatively connected to a variety of modules or components of the power trowel 100. For example, the illustrated controller 600 is connected to indicators 645, the motion sensor(s) 130a-130d, the tether detector 145, the kill switch(s) 150a-150f, an ON switch or trigger 650 (via a trigger switch 658), the motor 680 (via a power switching network 675), a load sensor 685, secondary sensors 690, a handle resistance module 695, and a power input unit 660. The battery pack 665 is connected to a battery pack interface 670 for mechanically and electrically connecting the battery pack 665 to the power trowel 100.

[0065] The controller 600 includes a plurality of electrical and electronic components that provide power, operational control, and protection to the components and modules within the controller 600 and/or power trowel 100. For example, the controller 600 includes, among other things, a processing unit 605 (e.g., a microprocessor, an electronic processor, an electronic

controller, a microcontroller, or another suitable programmable device), a memory 625, input units 630, and output units 635. The processing unit 605 includes, among other things, a control unit 610, an arithmetic logic unit (“ALU”) 615, and a plurality of registers 620 (shown as a group of registers in FIG. 6), and is implemented using a known computer architecture (e.g., a modified Harvard architecture, a von Neumann architecture, etc.). The processing unit 605, the memory 625, the input units 630, and the output units 635, as well as the various modules connected to the controller 600 are connected by one or more control and/or data buses (e.g., common bus 640). The control and/or data buses are shown generally in FIG. 6 for illustrative purposes. The use of one or more control and/or data buses for the interconnection between and communication among the various modules and components would be known to a person skilled in the art in view of the embodiments described herein.

[0066] The memory 625 is a non-transitory computer readable medium and includes, for example, a program storage area and a data storage area. The program storage area and the data storage area can include combinations of different types of memory, such as a ROM, a RAM (e.g., DRAM, SDRAM, etc.), EEPROM, flash memory, a hard disk, an SD card, or other suitable magnetic, optical, physical, or electronic memory devices. The processing unit 605 is connected to the memory 625 and executes software instructions that are capable of being stored in a RAM of the memory 625 (e.g., during execution), a ROM of the memory 625 (e.g., on a generally permanent basis), or another non-transitory computer readable medium such as another memory or a disc. Software included in the implementation of the power trowel 100 can be stored in the memory 625 of the controller 600. The software includes, for example, firmware, one or more applications, program data, filters, rules, one or more program modules, and other executable instructions. The controller 600 is configured to retrieve from the memory 625 and execute, among other things, instructions related to the control processes and methods described herein. In other embodiments, the controller 600 includes additional, fewer, or different components.

[0067] The controller 600 drives the motor 680 to rotate the blade assembly 125 in response to a user’s actuation of the trigger 650. The blade assembly 125 may be directly coupled to the motor 680 via an output shaft. In other embodiments, the blade assembly 125 is coupled to the motor 680 via a gearbox. Depression of the trigger 650 actuates a trigger switch 658, which outputs a signal to the controller 600 to drive the motor 680, and therefore the blade assembly 125. In some embodiments, the controller 600 drives the power switching network 675 (e.g., a

FET switching bridge) to drive the motor 680. For example, the power switching network 675 may include a plurality of high side switching elements (e.g., FETs) and a plurality of low side switching elements. The controller 600 may control each FET of the plurality of high side switching elements and the plurality of low side switching elements to drive each phase of the motor 680. When the trigger 650 is released, the controller 600 may apply a braking force to the motor 680. For example, the power switching network 675 may be controlled to more quickly deaccelerate the motor 680.

[0068] The indicators 645 are also connected to the controller 600 and receive control signals from the controller 600 to turn on and off or otherwise convey information based on different states of the power trowel 100. The indicators 645 include, for example, one or more light-emitting diodes (LEDs), or a display screen. The indicators 645 can be configured to display conditions of, or information associated with, the power trowel 100. For example, the indicators 645 can display information relating to the operational state of the power trowel 100 or battery pack 665, such as the charge capacity of the battery pack 665. The indicators 645 may also display information relating to a fault condition, or other abnormality, of the power trowel 100. In addition to or in place of visual indicators, the indicators 645 may also include a speaker or a tactile feedback mechanism to convey information to a user through audible or tactile outputs. In some embodiments, the indicators 645 display information relating to an uncontrolled condition or state of the power trowel 100 (e.g., a bind-up condition, a kickback condition, etc.). For example, one or more LEDs are activated upon detection of an uncontrolled state of the power trowel 100.

[0069] The motion sensor 130 senses motion of the power trowel 100. In some embodiments, the motion sensor 130 provides one or more motion signals (e.g., output signals) indicative of motion of the power trowel 100 to the controller 600. The controller 600 may determine, based on the motion signals, a position of the power trowel 100, such as an orientation of the power trowel 100 or an angle at which the shaft 115 is tilted. In some embodiments, the controller 600 determines an angular displacement, an angular velocity, or an angular acceleration of movement of the power trowel 100 (e.g., with respect to a vertical or z-axis with respect to ground) based on the motion signals.

[0070] The tether detector 145 provides a signal to the controller 600 indicative of whether the tether 140 is coupled to the power trowel 100. In some embodiments, the signal from the tether detector 145 is a binary signal (“1” or “ON” when the tether 140 is coupled to the power trowel 100, “0” or “OFF” when the tether 140 is not coupled to the power trowel 100).

[0071] The load sensor 685 provides load signals to the controller 600 indicative of load conditions of the power trowel 100. The controller 600 may determine, based on the load signals, a current draw of the motor 680, a power draw of the motor 680, a rotations-per-minute (RPM) of the motor 680, an RPM of the blade assembly 125, and the like. Accordingly, the load sensor 685 may include a current sensor, a voltage sensor, Hall sensors, etc. Additional sensors, such as voltage sensors, temperature sensors, and the like may be included in the secondary sensors 690 to detect additional conditions of the power trowel 100.

[0072] The kill switch 150a-150f outputs a signal to the controller 600 to stop operation of the motor 680. For example, upon actuation of the kill switch 150a-150f, the controller 600 initiates a braking operation of the motor 680 using the power switching network 675. In some embodiments, upon actuation of the kill switch 150a-150f, the controller 600 electrically disconnects the battery pack 665 from the power switching network 675, and therefore disconnects the battery pack 665 from the motor 680.

[0073] The controller 600 also monitors the handle resistance module 695 of the handle 105. In some embodiments, the controller 600 determines the resistance of the handle 105 based on a value of a current flowing through the handle 105 and/or a voltage of the handle 105. For example, the user’s hand adds a series or parallel resistance to a user detection electrical circuit (e.g., handle resistance module 695). The inclusion of the series or parallel resistance will increase or decrease the overall resistance of the circuit. The change in resistance can be detected by detecting a change in voltage across the resistance of the circuit. Similarly, when the user’s hand is removed from the handle, the resistance of the circuit again changes. If the resistance of the circuit changes by more than a threshold value, the power trowel 100 determines that one or both of the user’s hands have been removed from the handle. In some embodiments, first threshold is used to determine if one of the user’s hands has been removed, and a second threshold is used to determine if both of the user’s hands have been removed.

[0074] While operating the power trowel 100, a user may lose control of the power trowel 100, causing the power trowel 100 to begin spinning or experiencing other undesired motion. To protect the power trowel 100 and a user of the power trowel 100 when an uncontrolled condition occurs, the controller 600 performs protective operations in response to the detected uncontrolled state. For example, FIG. 7 is a flowchart of an example method 700 for controlling the power trowel 100 in response to a detected uncontrolled state. The method 700 may be performed by the controller 600. At block 705, the controller 600 operates the motor 680 to drive the blade assembly 125. For example, a user of the power trowel 100 actuates the trigger 650. Upon detecting actuation of the trigger 650, the controller 600 controls the power switching network 675 to supply power to the motor 680.

[0075] At block 710, the controller 600 receives one or more motion signals from the motion sensor 130a-130d. At block 715, the controller 600 determines, based on the motion signals from the motion sensor 130a-130d, whether a motion parameter (e.g., angular displacement, angular velocity, angular acceleration, etc.) of the power trowel 100 is greater than or equal to a threshold value. For example, the controller 600 determines, based on the one or more motion signals (e.g., velocity signals), the velocity or angular velocity of the power trowel 100. The angular velocity is compared to an angular velocity threshold (e.g., a velocity threshold) stored in the memory 625. If the angular velocity is not greater than or equal to the angular velocity threshold (i.e., a controlled state), the controller 600 returns to block 705 and continues to operate the motor 680 to drive the blade assembly 125. Accordingly, in some embodiments, the controller 600 continuously monitors the angular velocity of the power trowel 100. If the angular velocity is greater than or equal to the angular velocity threshold (i.e., an uncontrolled state), at block 720, the controller 600 adjusts operation of the motor 680. In some embodiments, the controller 600 deactivates or otherwise stops operation of the motor 680. The controller 600 may disconnect the battery pack 665 from the power switching network 675 such that the motor 680 no longer receives power. In some embodiments, the controller 600 reduces an amount of power provided to the motor 680. For example, the amount of power provided to the motor 680 is decreased to a non-zero value to allow a user to regain control of the power trowel 100.

[0076] FIG. 8 is a flowchart of another example method 800 for controlling the power trowel 100 in response to a detected uncontrolled state. The method 800 may be performed by the

controller 600. At block 805, the controller 600 operates the motor 680 to drive the blade assembly 125, as previously described with respect to block 705. At block 810, the controller 600 receives one or more motion signals from the motion sensor 130a-130d. At block 815, the controller 600 determines, based on the motion signals from the motion sensor 130, whether a position of the power trowel 100 is greater than or equal to a position threshold. For example, the controller 600 may determine, based on the motion signals, an orientation of the power trowel 100. The controller 600 compares the orientation of the power trowel 100 to an orientation threshold. In some embodiments, the orientation of the power trowel 100 includes an angle of the power trowel 100, such as an angle of the shaft 115 (e.g., with respect to gravity). Accordingly, the controller 600 may compare the angle of the shaft 115 to an angle threshold.

[0077] If the position of the power trowel 100 is not greater than or equal to the position threshold (i.e., a controlled state), the controller 600 returns to block 805 and continues to operate the motor 680 to drive the blade assembly 125. If the position of the power trowel 100 is greater than or equal to the position threshold (i.e., an uncontrolled state), at block 820, the controller 600 adjusts operation of the motor 680. In some embodiments, the controller 600 deactivates or otherwise stops operation of the motor 680. The controller 600 may disconnect the battery pack 665 from the power switching network 675 such that the motor 680 no longer receives power. In some embodiments, the controller 600 reduces an amount of power provided to the motor 680. For example, the amount of power provided to the motor 680 is decreased to a non-zero value to allow a user to regain control of the power trowel 100.

[0078] FIG. 9 is a flowchart of another example method 900 for controlling the power trowel 100 in response to a detected uncontrolled state. The method 900 may be performed by the controller 600. At block 905, the controller 600 operates the motor 680 to drive the blade assembly 125, as previously described with respect to block 705. At block 910, the controller 600 receives load signals from the load sensor 685. At block 915, the controller 600 determines, based on the load signals from the load sensor 685, whether the load on the motor 680 (e.g., a load condition of the motor 680) is greater than or equal to a load threshold. For example, the controller 600 may determine, based on the load signal, a current draw of the motor 680. The controller 600 then compares the current draw of the motor 680 to a current threshold. In some embodiments, the controller 600 determines a power draw of the motor 680 based on the load signal. The controller 600 then compares the power draw of the motor 680 to a power threshold.

In some embodiments, the controller 600 determines an RPM of the motor 680 based on the load signal. The controller 600 then compares the RPM of the motor 680 to a rotation speed threshold.

[0079] If the load of the motor 680 is not greater than or equal to the load threshold (i.e., an uncontrolled state), the controller 600 returns to block 905 and continues to operate the motor 680 to drive the blade assembly 125. If the load of the motor 680 is greater than or equal to the load threshold (i.e., an uncontrolled state), at block 920, the controller 600 adjusts operation of the motor 680. In some embodiments, the controller 600 deactivates or otherwise stops operation of the motor 680. The controller 600 may disconnect the battery pack 665 from the power switching network 675 such that the motor 680 no longer receives power. In some embodiments, the controller 600 reduces an amount of power provided to the motor 680. For example, the amount of power provided to the motor 680 is decreased to a non-zero value to allow a user to regain control of the power trowel 100.

[0080] In some embodiments, the controller 600 determines, based on the load signals from the load sensor 685, whether the load on the motor 680 is within a predetermined load operating range (e.g., between an upper load threshold and a lower load threshold). If the load of the motor 680 is within the predetermined load operating range, the controller 600 returns to block 905 and continues to operate the motor 680 to drive the blade assembly 125. If the load of the motor 680 is outside of the predetermined load operating range, at block 920, the controller 600 adjusts operation of the motor 680.

[0081] At times, an operator may let go of the handle 105, resulting in the power trowel 100 being in an uncontrolled state. FIG. 10 is a flowchart of an example method 1000 for detecting whether an operator is holding on to the handle 105 of the power trowel 100. The method 1000 may be performed by the controller 600. At block 1005, the controller 600 operates the motor 680 to drive the blade assembly 125, as previously described with respect to block 705.

[0082] At block 1010, the controller 600 determines whether an operator is holding the handle 105. For example, the controller 600 may monitor the resistance of the handle 105. If a change in the resistance of the handle 105 is greater than a threshold, the controller 600 determines the operator is not holding the handle 105. In some embodiments, the controller 600 receives a signal from the tether detector 145. If the signal from the tether detector 145 indicates

the tether 140 is not connected to the power trowel 100, the controller 600 determines that the operator is not holding the handle 105. In some embodiments, the controller 600 determines whether the switch 108 (or trigger 650) is actuated. If the switch 108 is not actuated, the controller 600 determines that the operator is not holding the handle 105.

[0083] If an operator is holding the handle 105 (i.e., a controlled state), the controller 600 returns to block 1005 and continues to operator the motor 680 to drive the blade assembly 125. If the controller 600 determines an operator is not holding the handle 105 (i.e., an uncontrolled state), the controller 600 continues to block 1015 and adjusts operation of the motor 680. In some embodiments, the controller 600 deactivates or otherwise stops operation of the motor 680. The controller 600 may disconnect the battery pack 665 from the power switching network 675 such that the motor 680 no longer receives power. In some embodiments, the controller 600 reduces an amount of power provided to the motor 680. For example, the amount of power provided to the motor 680 is decreased to a non-zero value to allow a user to regain control of the power trowel 100.

[0084] Accordingly, implementation of the method 700, the method 800, the method 900, and/or the method 1000 may assist an operator of the power trowel 100 in regaining control of the power trowel 100 when the controller 600 determines the power trowel is in an uncontrolled state.

[0085] Thus, embodiments provided herein describe, among other things, systems and methods for determining and reacting to a kickback event or an otherwise uncontrolled state of a power trowel. Various features and advantages are set forth in the following claims.

CLAIMS

What is claimed is:

1. A power trowel comprising:
 - a handle;
 - a housing;
 - a blade assembly;
 - a motor coupled to the blade assembly;
 - a motion sensor configured to provide an output signal indicative of a motion of the power trowel, wherein the output signal includes an orientation signal indicative of an orientation of the power trowel; and
 - a controller connected to the motor and the motion sensor, the controller configured to:
 - receive the orientation signal from the motion sensor,
 - determine, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold, and
 - deactivate the motor in response to the orientation of the power trowel being greater than or equal to the orientation threshold.
2. The power trowel of claim 1, wherein:
 - the output signal includes a velocity signal indicative of a velocity of motion of the power trowel; and
 - the controller is further configured to:
 - determine whether the velocity signal is greater than or equal to a velocity threshold, and
 - deactivate the motor in response to the velocity signal being greater than or equal to the velocity threshold.
3. The power trowel of claim 1, wherein the motion sensor is located on the handle.
4. The power trowel of claim 3, wherein the orientation of the power trowel is an angle of the handle.

5. The power trowel of claim 1, wherein the motion sensor is located on the housing.
6. The power trowel of claim 1, further comprising:
 - a battery pack connected to the motor; and
 - a switch connected to the controller, the battery pack, and the motor,wherein the controller is further configured to:
 - operate, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, the switch to disconnect the battery pack from the motor.
7. The power trowel of claim 1, further comprising:
 - a load sensor configured to provide a load signal indicative of a load condition of the motor,wherein the controller is further configured to:
 - monitor the load condition of the motor, and
 - deactivate the motor in response to the load condition of the motor being outside a predetermined load operating range.
8. The power trowel of claim 7, wherein the load condition is at least one selected from the group consisting of: a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.
9. A power trowel comprising:
 - a handle;
 - a housing;
 - a blade assembly;
 - a motor coupled to the blade assembly;
 - a detector for detecting whether an operator is holding the handle; and
 - a controller connected to the motor and the detector, the controller configured to:
 - operate the motor to drive the blade assembly,
 - determine whether the operator is holding the handle, and

deactivate the motor in response to determining the operator is not holding the handle.

10. The power trowel of claim 9, wherein:
the detector is a lever operable to be actuated by the operator; and
the controller is further configured to:
determine the operator is holding the handle when the lever is actuated, and
determine the operator is not holding the handle when the lever is not actuated.
11. The power trowel of claim 9, further comprising:
a battery pack configured to provide power to the motor, and
wherein the controller is further configured to:
disconnect, in response to determining the operator is not holding the handle, the
battery pack from the motor.
12. The power trowel of claim 9, wherein:
the detector is a tether configured to be connected to the power trowel; and
the controller is further configured to:
determine whether the tether is connected to the power trowel; and
deactivate the motor in response to determining the tether is not connected to the
power trowel.
13. The power trowel of claim 9, further comprising a switch configured to deactivate, in
response to being actuated, the motor.
14. The power trowel of claim 9, wherein:
the detector is a metal conductor integrated into the handle; and
the controller is further configured to:
monitor a resistance of the metal conductor, and
deactivate the motor in response to detecting a change in the resistance of the
metal conductor.

15. A power trowel comprising:
a handle;
a housing;
a blade assembly;
a motor coupled to the blade assembly;
a battery pack configured to provide power to the motor;
a motion sensor configured to provide an output signal indicative of a motion of the housing, wherein the output signal includes an orientation signal indicative of an orientation of the power trowel; and
a controller connected to the motor and the motion sensor, the controller configured to:
receive the orientation signal from the motion sensor,
determine, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold, and
decrease, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, an amount of power provided by the battery pack to the motor.
16. The power trowel of claim 15, wherein the amount of power provided by the battery pack to the motor is decreased to a non-zero value.
17. The power trowel of claim 15, wherein:
the output signal includes a velocity signal indicative of a velocity of a motion of the power trowel; and
the controller is further configured to:
determine whether the velocity signal is greater than or equal to a velocity threshold, and
decrease, in response to the velocity signal being greater than or equal to the velocity threshold, the amount of power provided by the battery pack to the motor.
18. The power trowel of claim 15, wherein the motion sensor is located on the handle.

19. The power trowel of claim 15, further comprising:
a load sensor configured to provide a load signal indicative of a load condition of the motor,
wherein the controller is further configured to:
monitor the load condition of the motor, and
decrease, in response to the load condition of the motor being outside a predetermined load operating range, the amount of power provided by the battery pack to the motor.
20. The power trowel of claim 19, wherein the load condition is at least one selected from the group consisting of: a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.
21. A method of operating a power trowel, the method comprising:
operating a motor coupled to a blade assembly to drive the blade assembly;
receiving an orientation signal from a motion sensor, the orientation signal being indicative of an orientation of the power trowel;
determining, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold; and
deactivating the motor in response to the orientation of the power trowel being greater than or equal to the orientation threshold.
22. The method of claim 21, further comprising:
providing, from the motion sensor, an output signal indicative of a motion of the power trowel, the output signal including the orientation signal, wherein the output signal includes a velocity signal indicative of a velocity of motion of the power trowel;
determining whether the velocity signal is greater than or equal to a velocity threshold;
and
deactivating the motor in response to the velocity signal being greater than or equal to the velocity threshold.

23. The method of claim 21, wherein the motion sensor is located on a handle of the power trowel.

24. The method of claim 23, wherein the orientation of the power trowel is an angle of the handle.

25. The method of claim 21, wherein the motion sensor is located on a housing of the power trowel.

26. The method of claim 21, further comprising:
operating, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, a switch to disconnect a battery pack from the motor.

27. The method of claim 21, further comprising:
monitoring, based on a load signal received from a load sensor, a load condition of the motor; and
deactivating the motor in response to the load condition of the motor being outside a predetermined load operating range.

28. The method of claim 27, wherein the load condition is at least one selected from the group consisting of: a current draw of the motor, a power draw of the motor, a rotations-per-minute ("RPM") of the motor, and an RPM of the blade assembly.

29. A method of operating a power trowel, the method comprising:
operating a motor coupled to a blade assembly to drive the blade assembly;
determining, via a detector device, whether an operator is holding a handle of the power trowel; and
deactivating the motor in response to determining the operator is not holding the handle.

30. The method of claim 29, wherein the detector device is a lever operable to be actuated by the operator, and wherein the method further comprises:

determining the operator is holding the handle when the lever is actuated; and
determining the operator is not holding the handle when the lever is not actuated.

31. The method of claim 29, further comprising:
disconnecting, in response to determining the operator is not holding the handle, a battery pack from the motor.
32. The method of claim 29, wherein the detector device is a tether, and wherein the method further comprises:
determining whether the tether is connected to the power trowel; and
deactivating the motor in response to determining the tether is not connected to the power trowel.
33. The method of claim 29, further comprising:
deactivating the motor in response to a switch being actuated.
34. The method of claim 29, wherein the detector device is a metal conductor integrated into the handle, and wherein the method further comprises:
monitoring a resistance of the metal conductor; and
deactivating the motor in response to detecting a change in the resistance of the metal conductor.
35. A method of operating a power trowel, the method comprising:
operating a motor coupled to a blade assembly to drive the blade assembly;
receiving an orientation signal from a motion sensor, the orientation signal being indicative of an orientation of the power trowel;
determining, based on the orientation signal, whether the orientation of the power trowel is greater than or equal to an orientation threshold; and
decreasing, in response to the orientation of the power trowel being greater than or equal to the orientation threshold, an amount of power provided by a battery pack to the motor.

36. The method of claim 35, wherein the amount of power provided by the battery pack to the motor is decreased to a non-zero value.

37. The method of claim 35, further comprising:

providing, from the motion sensor, an output signal indicative of a motion of the power trowel, the output signal including the orientation signal, wherein the output signal includes a velocity signal indicative of a velocity of motion of the power trowel;

determining whether the velocity signal is greater than or equal to a velocity threshold; and

decreasing, in response to the velocity signal being greater than or equal to the velocity threshold, the amount of power provided by the battery pack to the motor.

38. The method of claim 35, wherein the motion sensor is located on a handle of the power trowel.

39. The method of claim 35, further comprising:

monitoring, based on a load signal received from a load sensor, a load condition of the motor; and

decreasing, in response to the load condition of the motor being outside a predetermined load operating range, the amount of power provided by the battery pack to the motor.

40. The method of claim 39, wherein the load condition is at least one selected from the group consisting of: a current draw of the motor, a power draw of the motor, a rotations-per-minute (“RPM”) of the motor, and an RPM of the blade assembly.

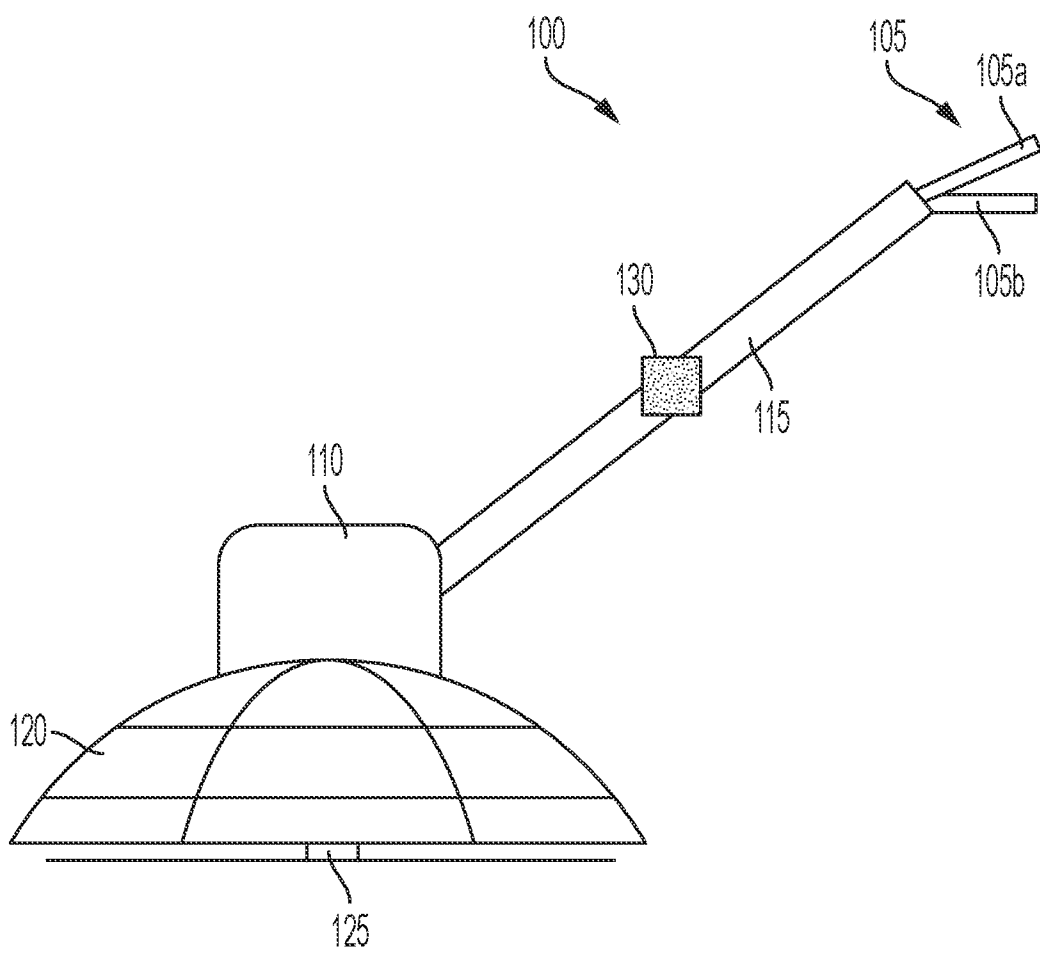


FIG. 1

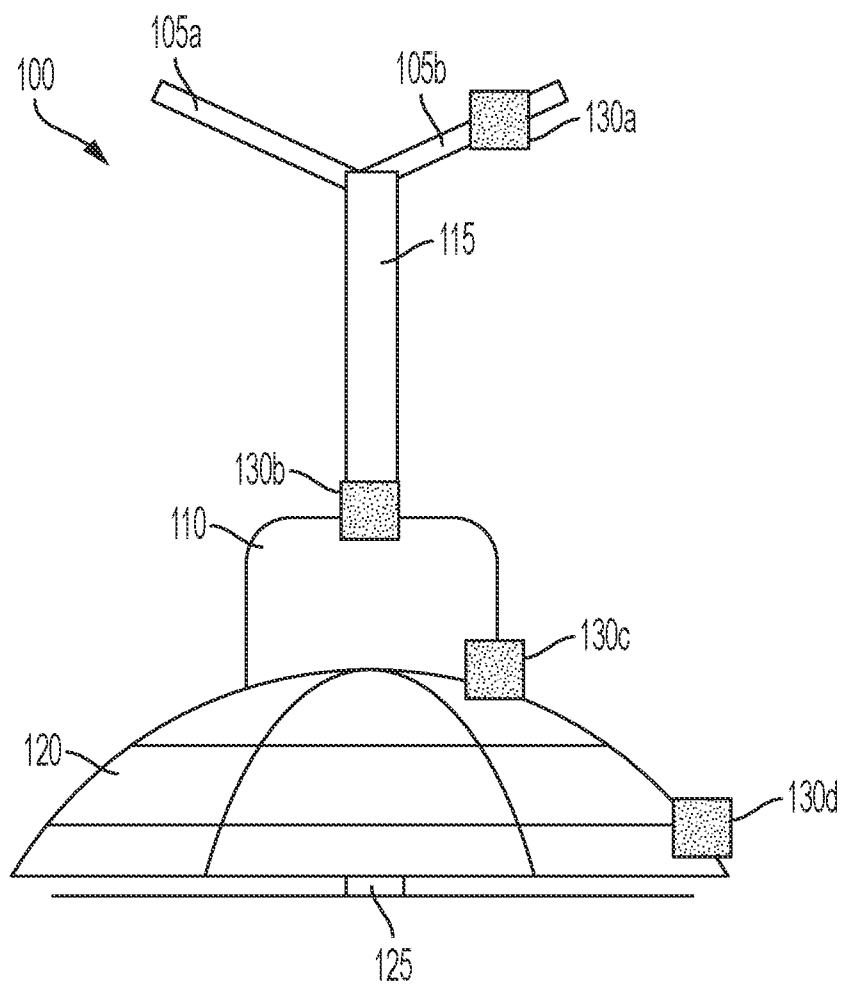


FIG. 2

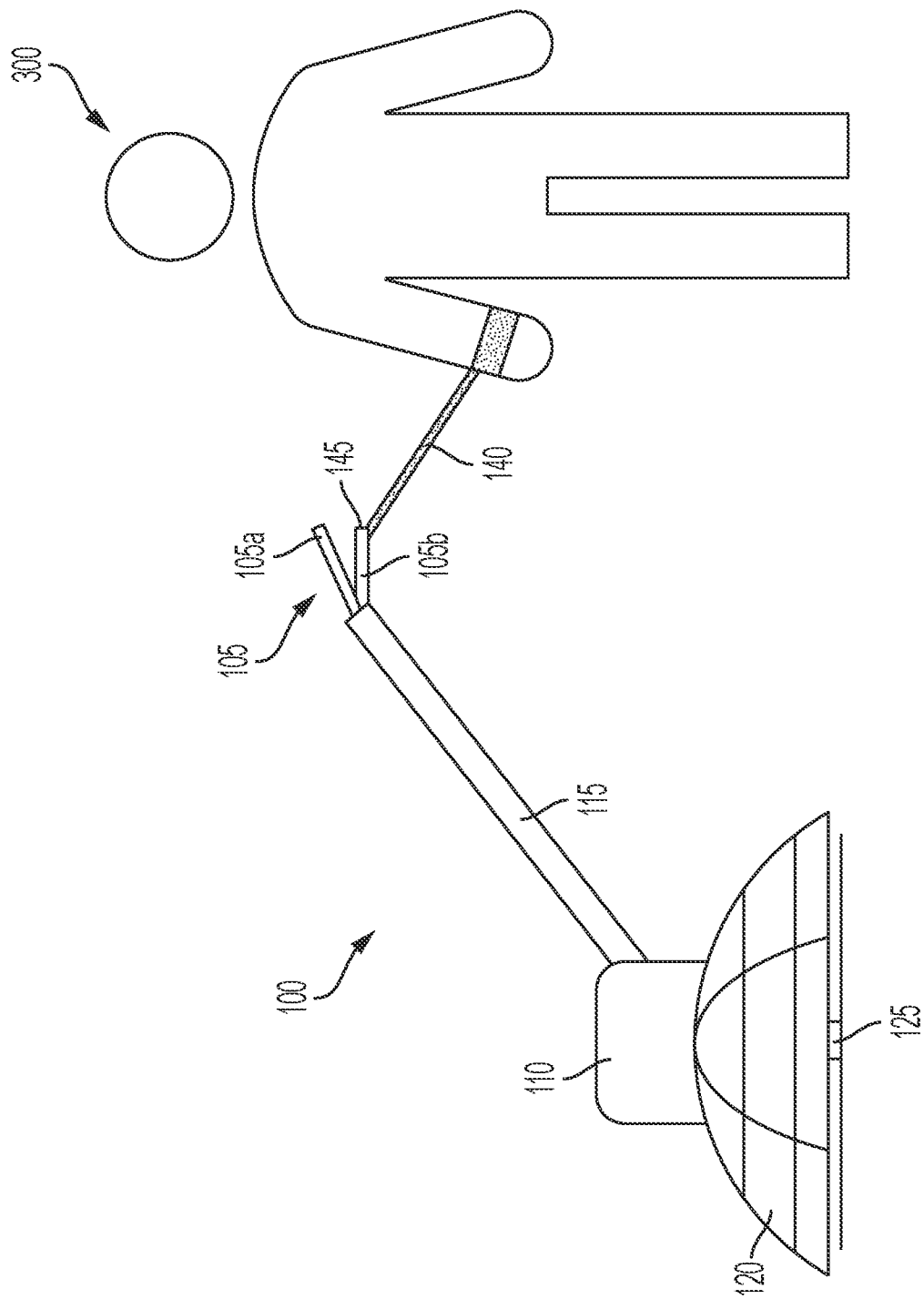


FIG. 3

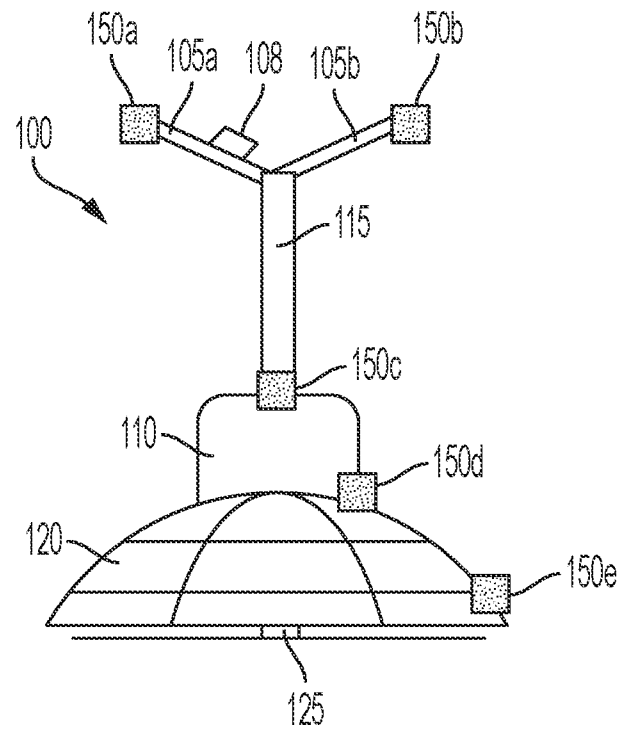


FIG. 4A

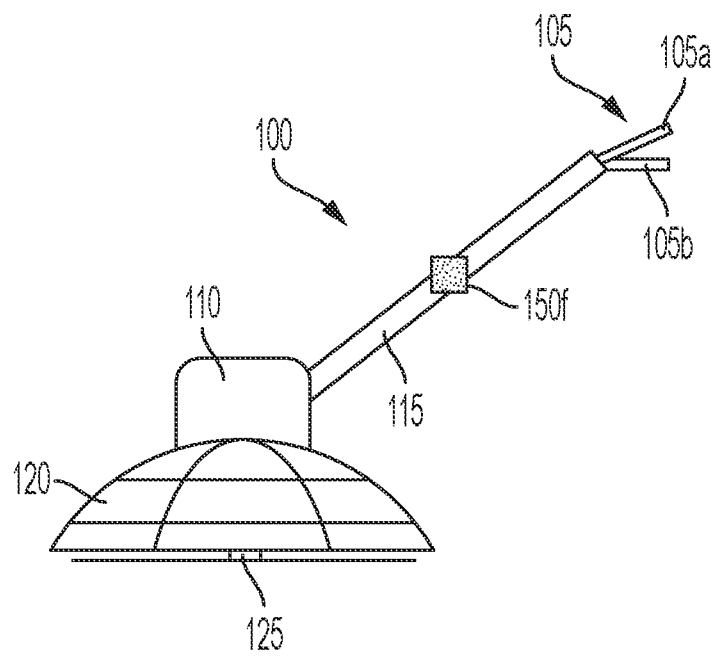


FIG. 4B

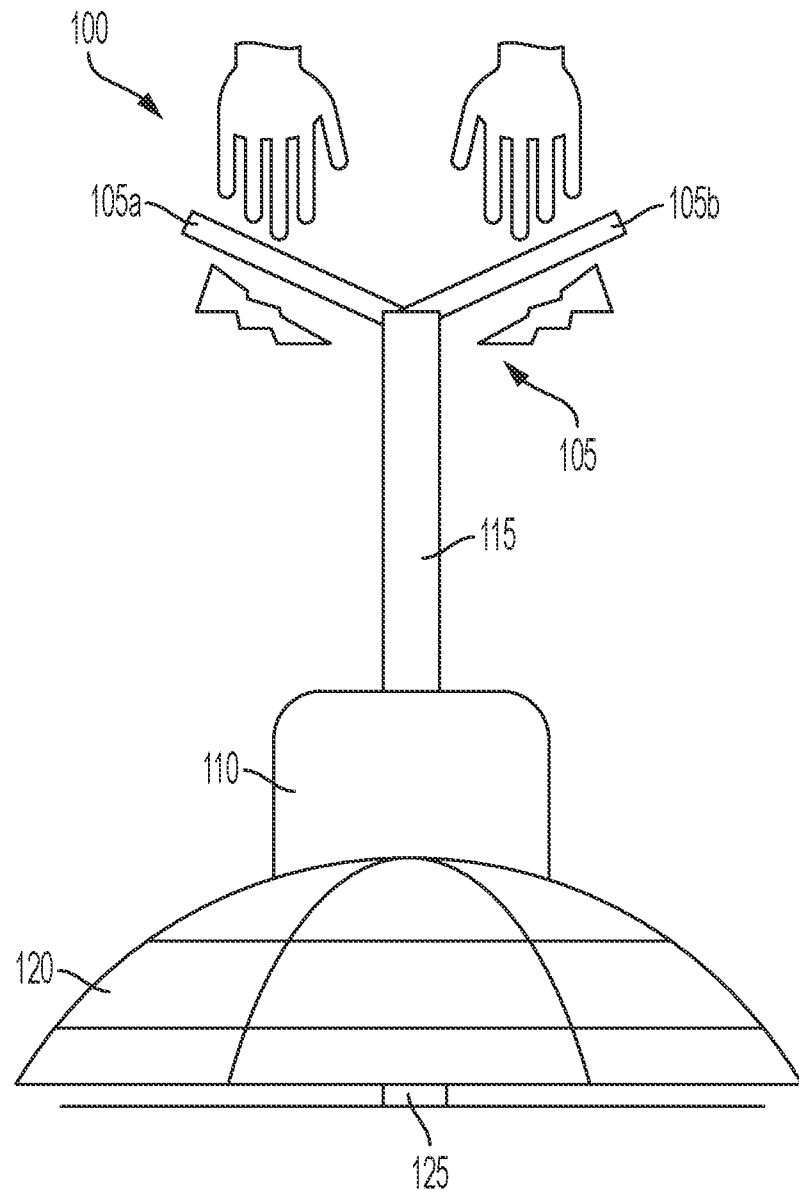


FIG. 5

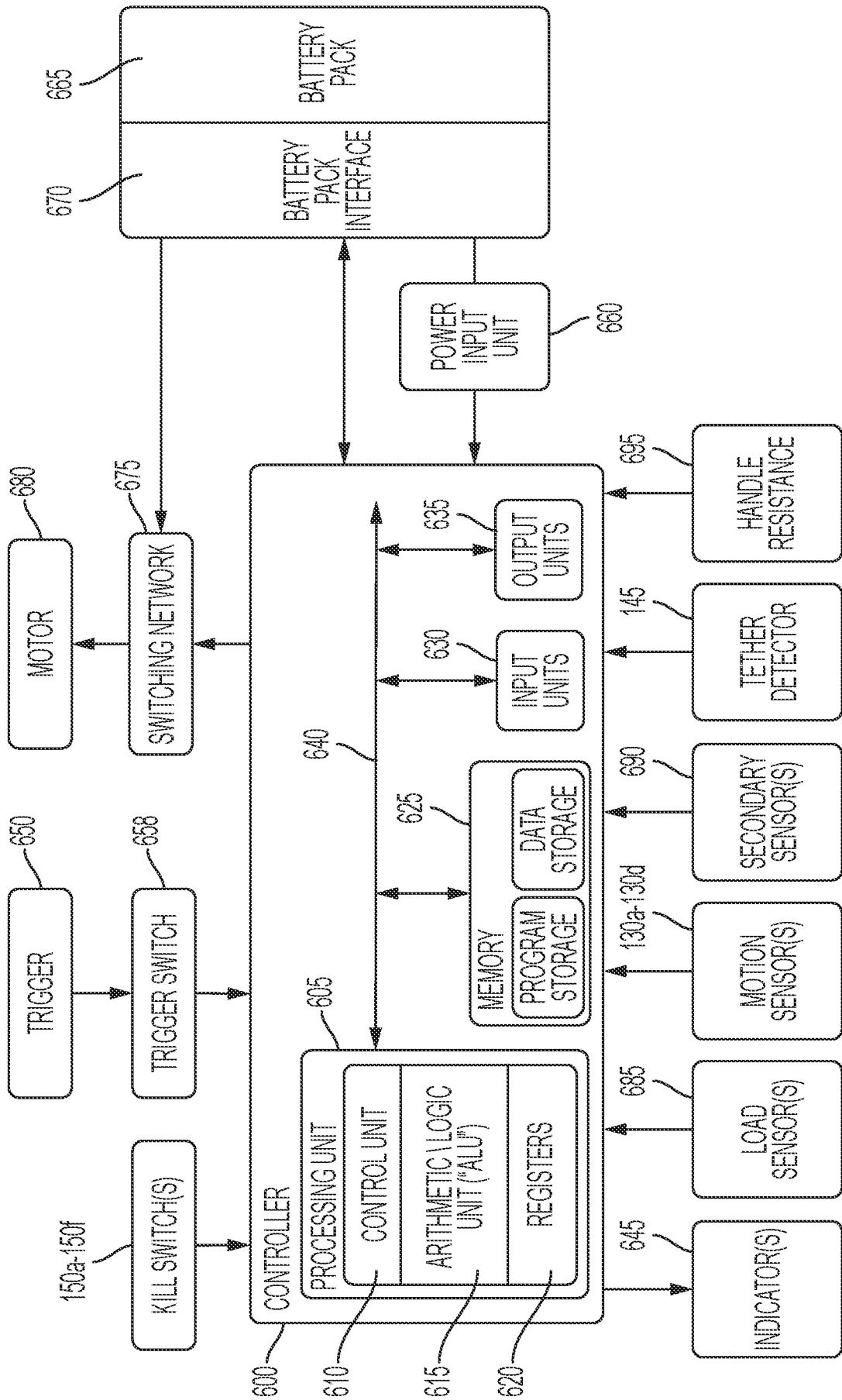


FIG. 6

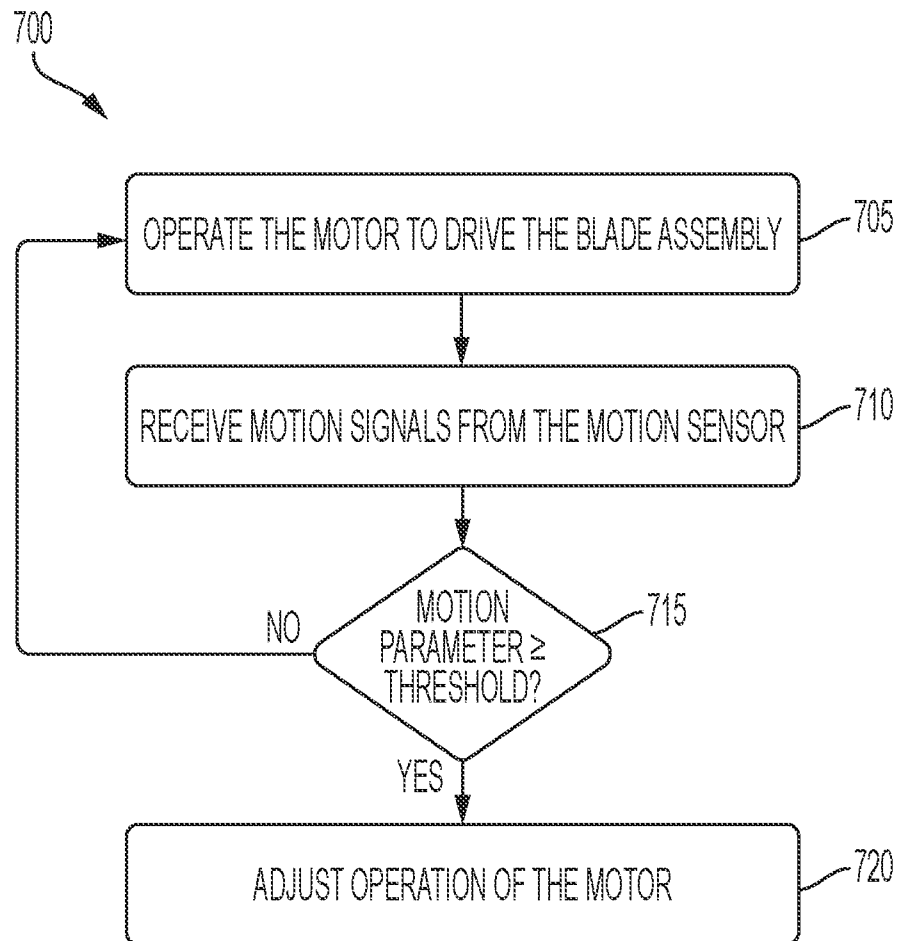


FIG. 7

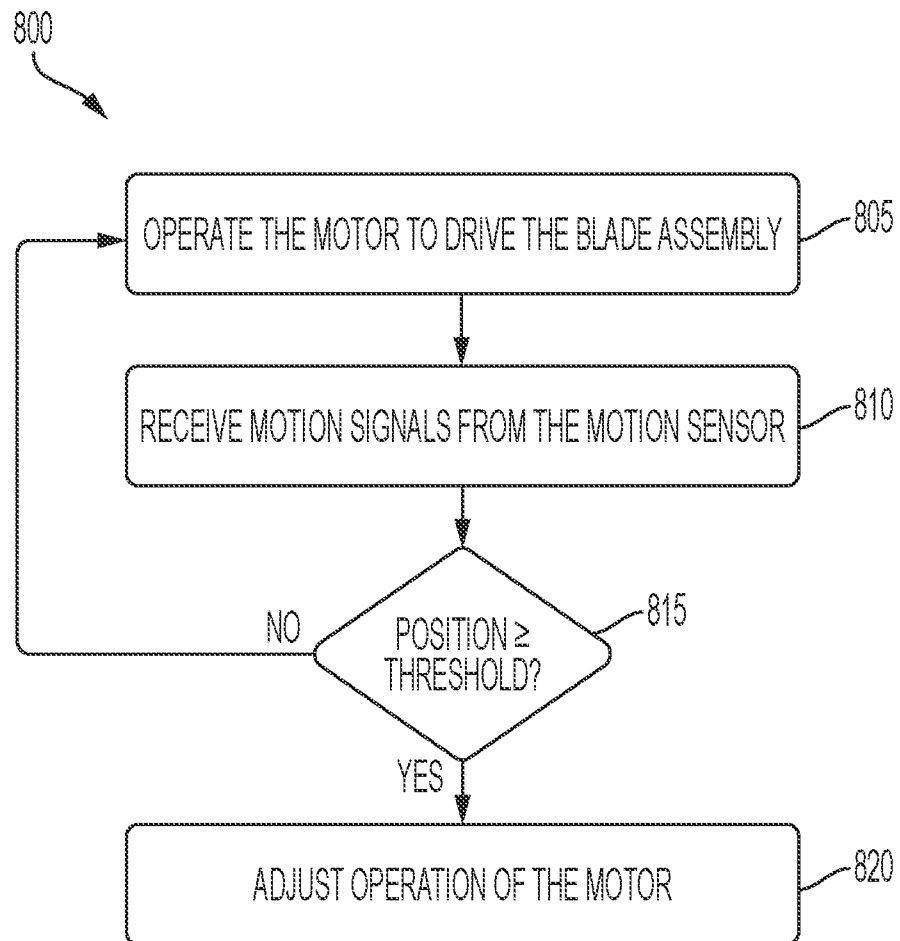


FIG. 8

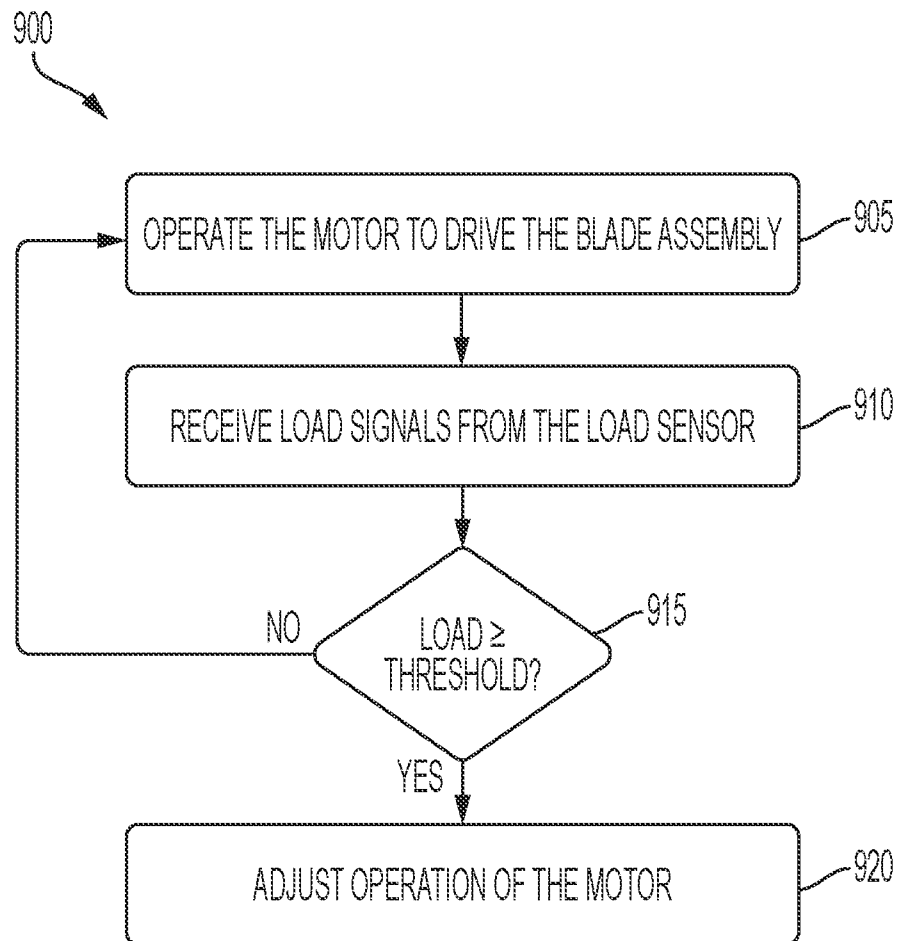


FIG. 9

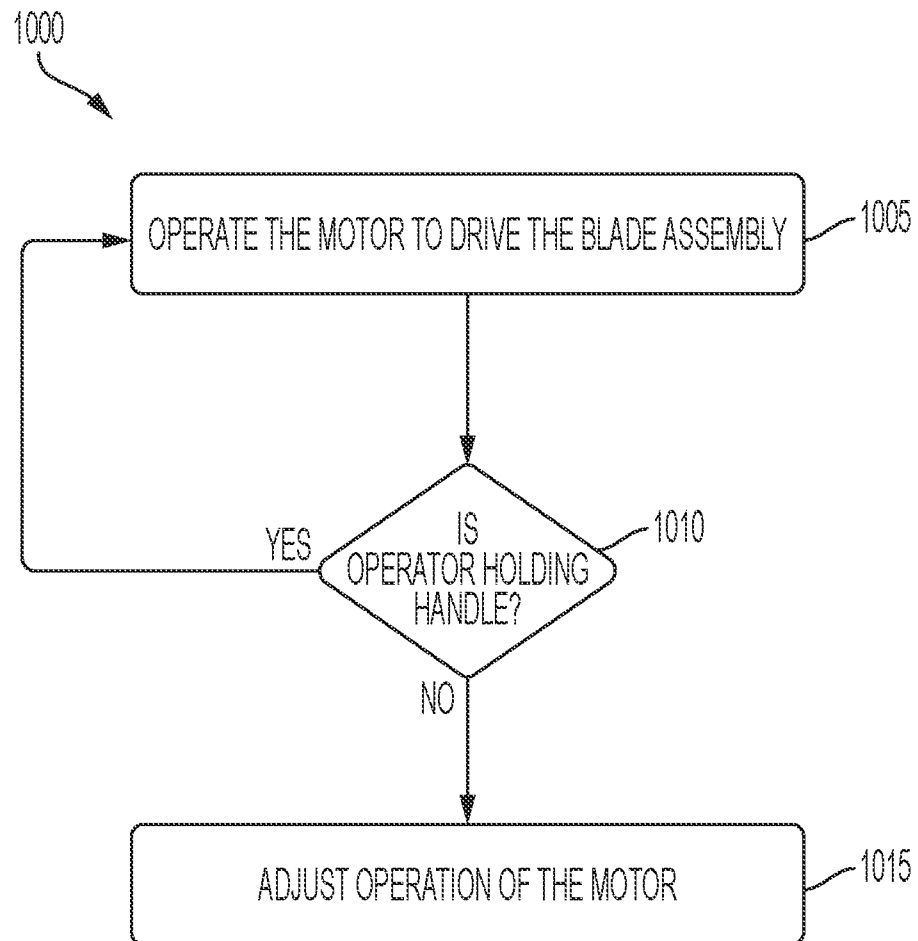


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2022/080616

A. CLASSIFICATION OF SUBJECT MATTER E04F 21/16(2006.01)i; G06F 3/01(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) E04F 21/16(2006.01); B23Q 11/00(2006.01); E01C 19/22(2006.01); E01C 19/35(2006.01); E01C 19/42(2006.01); E02D 3/074(2006.01); F02D 45/00(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: power trowel, handle, housing, blade assembly, motor, motion sensor, controller, orientation signal, battery		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 110820484 A (BENGBU CITY CIRCULATION RATE ELECTRONIC TECHNOLOGY CO., LTD.) 21 February 2020 (2020-02-21) paragraphs [0015], [0034] and figures 1-2	1,3-4,6,21,23-24,26,29,33
Y		2,5,7-20,22,25,27-28,30-32,34-40
Y	US 6846127 B1 (BRAUN et al.) 25 January 2005 (2005-01-25) column 5, line 8 - column 7, line 57 and figures 1-2, 6	2,5,17,22,25,37
Y	US 2014-0076596 A1 (HONDA MOTOR CO., LTD.) 20 March 2014 (2014-03-20) paragraph [0034] and figures 5-6	7-8,19-20,27-28,39-40
Y	US 2011-0164923 A1 (QUENZI et al.) 07 July 2011 (2011-07-07) paragraphs [0087], [0194] and figure 33	9-20,30-31,35-40
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "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 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "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 07 April 2023		Date of mailing of the international search report 07 April 2023
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Tae Wook Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2022/080616**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 6474300 B1 (STEFFEN, MICHAEL) 05 November 2002 (2002-11-05) column 4, lines 16-31 and figure 1	14,34

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Information on patent family members

International application No.

PCT/US2022/080616

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