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Radtke et al.

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(54) **BATTERY PACK POWERED ROLL GROOVER**

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(Continued)

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(52) **U.S. Cl.**
CPC ***B21D 17/04*** (2013.01)

(58) **Field of Classification Search**
CPC B21D 17/00; B21D 17/04; B21H 7/182
See application file for complete search history.

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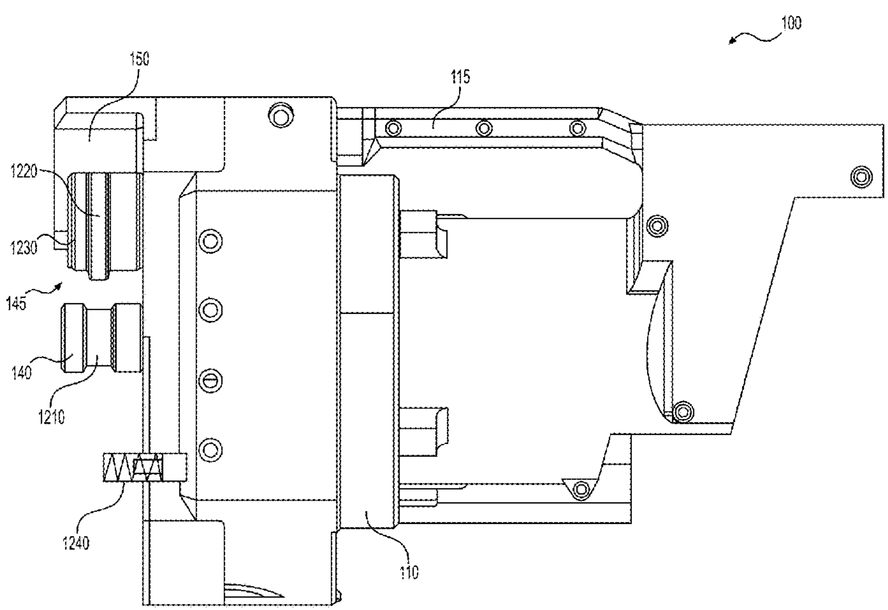
(57) **ABSTRACT**

Battery pack powered roll groover described herein includes a housing, an inner roller provided on the housing and configured to be received in an inner circumference of a workpiece, a groove roll provided on the housing and configured to produce a groove on the workpiece, one or more motors provided within the housing and configured to drive the groove roll, and an electronic processor electrically connected to the one or more motors. The electronic processor is configured to operate the one or more motors to perform a first operation of moving the groove roll in a radial direction, and operate the one or more motors to perform a second operation of moving the groove roll around a track in a circumferential direction. The first operation is performed to adjust a groove depth on the workpiece. The second operation is performed to produce the groove on the workpiece.

18 Claims, 14 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 63/235,507, filed on Aug. 20, 2021, provisional application No. 63/093,577, filed on Oct. 19, 2020.

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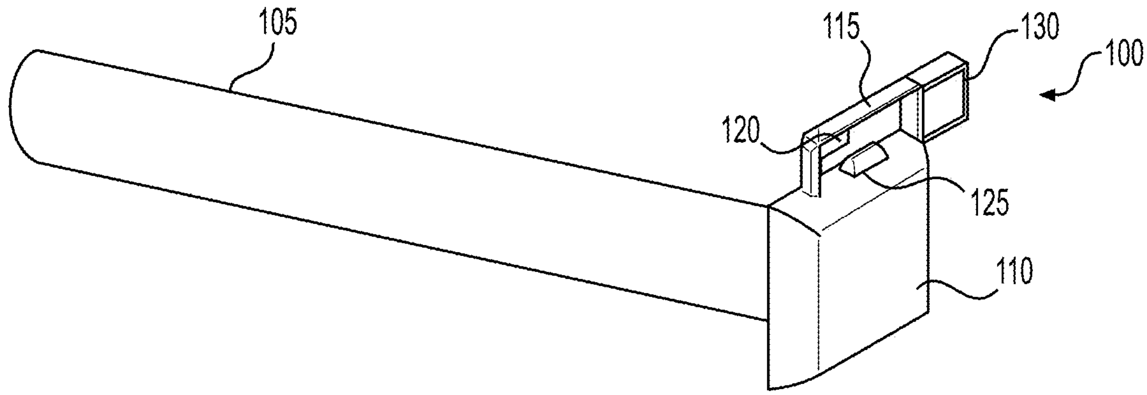
105
115
130
100
120
125
110

FIG. 1

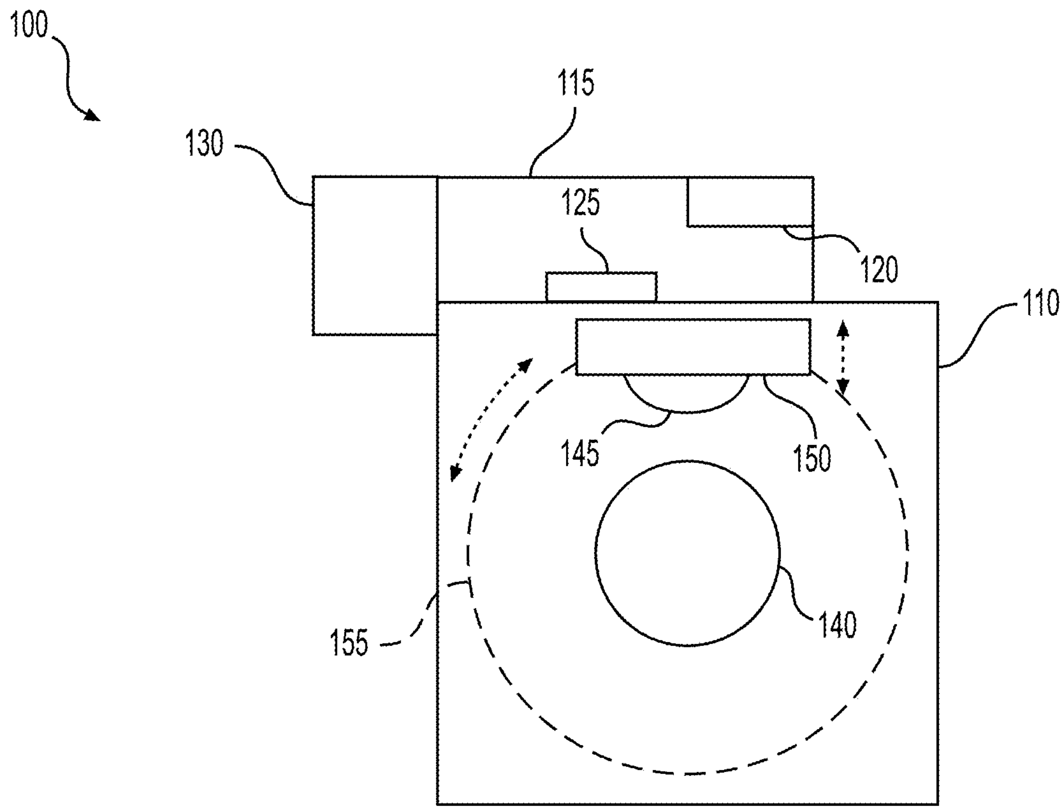
100
115
130
125
120
110
145
150
140
155

FIG. 2

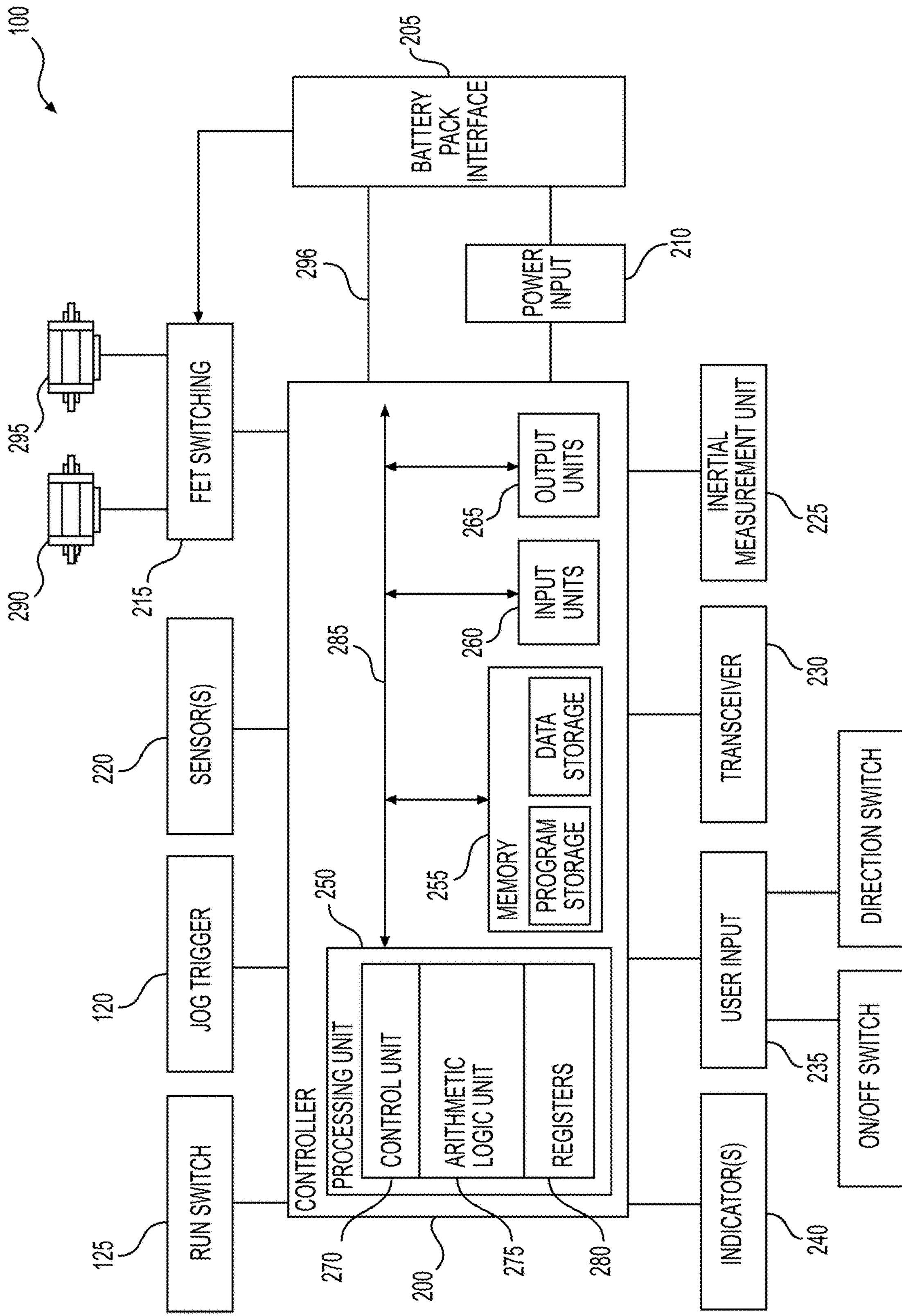
100
BATTERY PACK INTERFACE
205
296
POWER INPUT
210
FET SWITCHING
215
290
295
SENSOR(S)
220
JOG TRIGGER
120
RUN SWITCH
125
CONTROLLER
200
PROCESSING UNIT
250
CONTROL UNIT
270
ARITHMETIC LOGIC UNIT
275
REGISTERS
280
285
MEMORY
255
PROGRAM STORAGE
DATA STORAGE
INPUT UNITS
260
OUTPUT UNITS
265
INERTIAL MEASUREMENT UNIT
225
TRANSCEIVER
230
USER INPUT
235
ON/OFF SWITCH
236
DIRECTION SWITCH
237
INDICATOR(S)
240

FIG. 3A

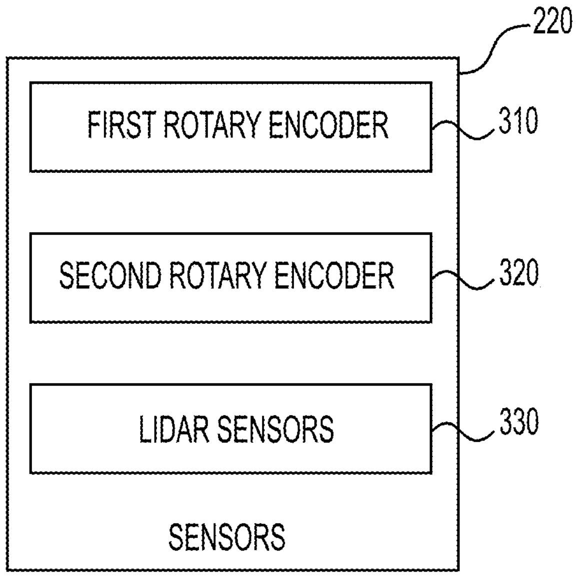
220
FIRST ROTARY ENCODER
310
SECOND ROTARY ENCODER
320
LIDAR SENSORS
330
SENSORS

FIG. 3B

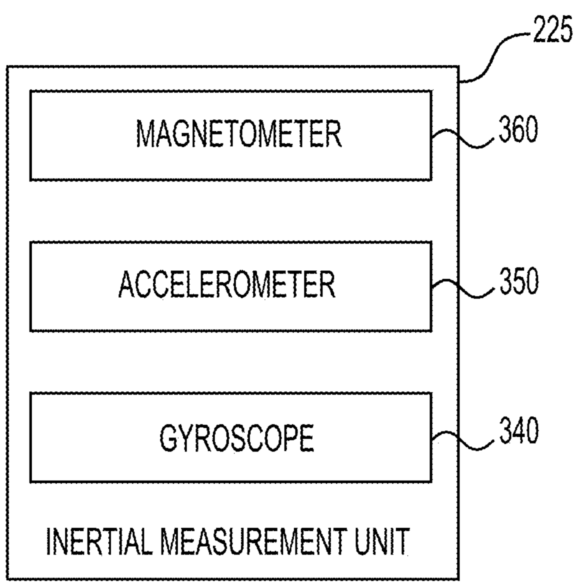
225
MAGNETOMETER
360
ACCELEROMETER
350
GYROSCOPE
340
INERTIAL MEASUREMENT UNIT

FIG. 3C

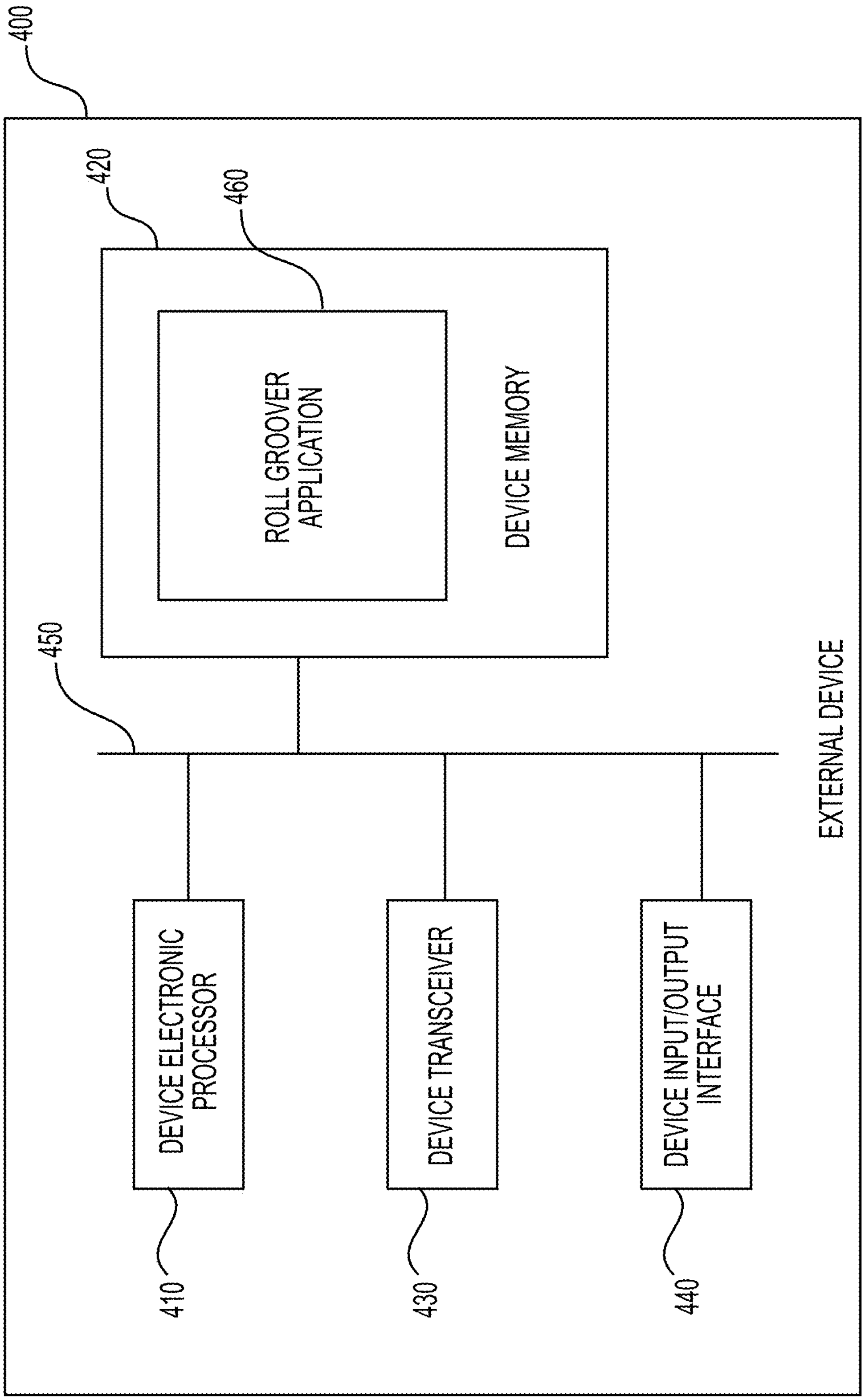
400
420
460
ROLL GROOVER
APPLICATION
DEVICE MEMORY
450
EXTERNAL DEVICE
DEVICE ELECTRONIC
PROCESSOR
DEVICE TRANSCEIVER
DEVICE INPUT/OUTPUT
INTERFACE
410
430
440

FIG. 4

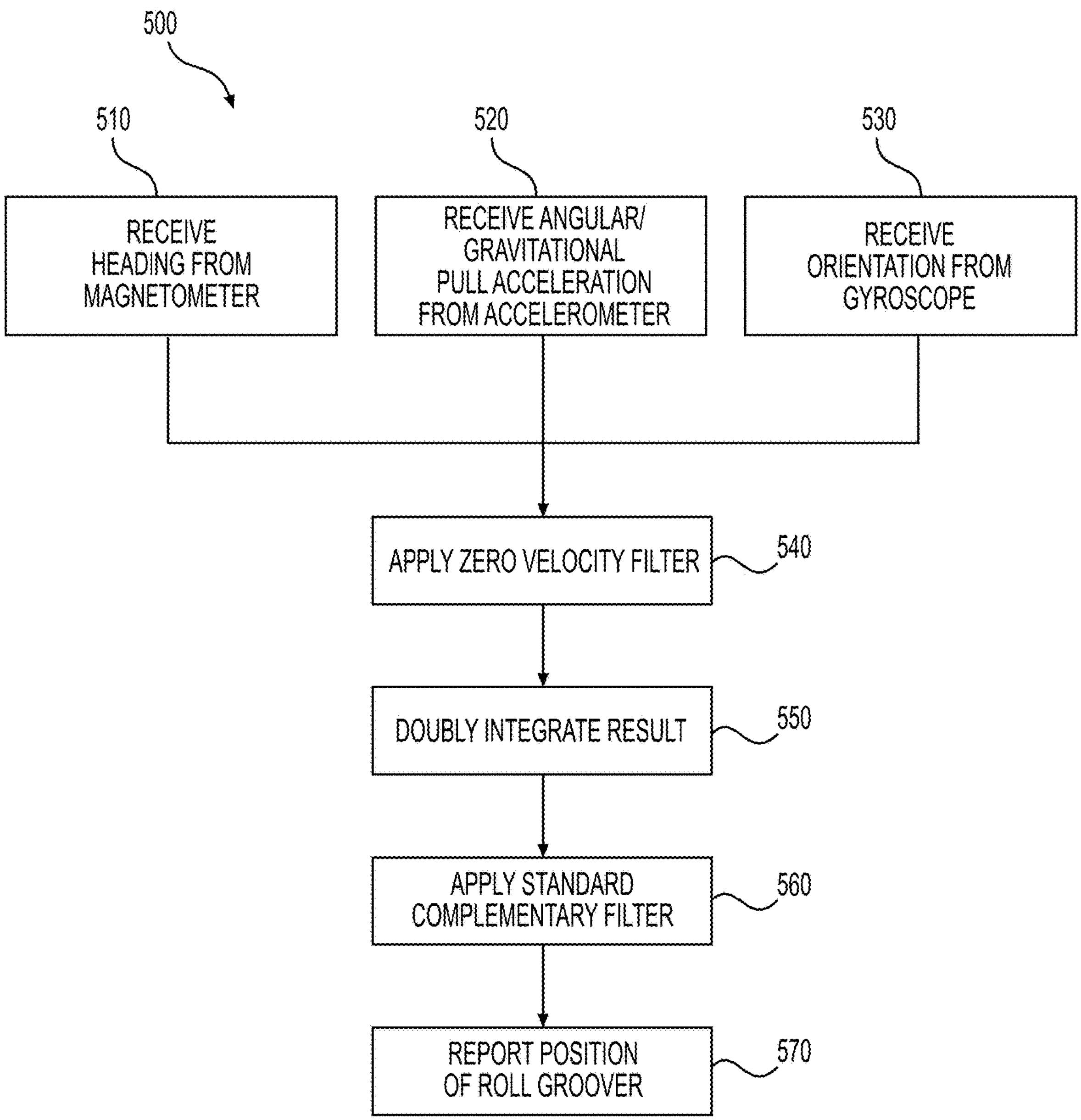
500
510
RECEIVE HEADING FROM MAGNETOMETER
520
RECEIVE ANGULAR/ GRAVITATIONAL PULL ACCELERATION FROM ACCELEROMETER
530
RECEIVE ORIENTATION FROM GYROSCOPE
APPLY ZERO VELOCITY FILTER
540
DOUBLY INTEGRATE RESULT
550
APPLY STANDARD COMPLEMENTARY FILTER
560
REPORT POSITION OF ROLL GROOVER
570

FIG. 5

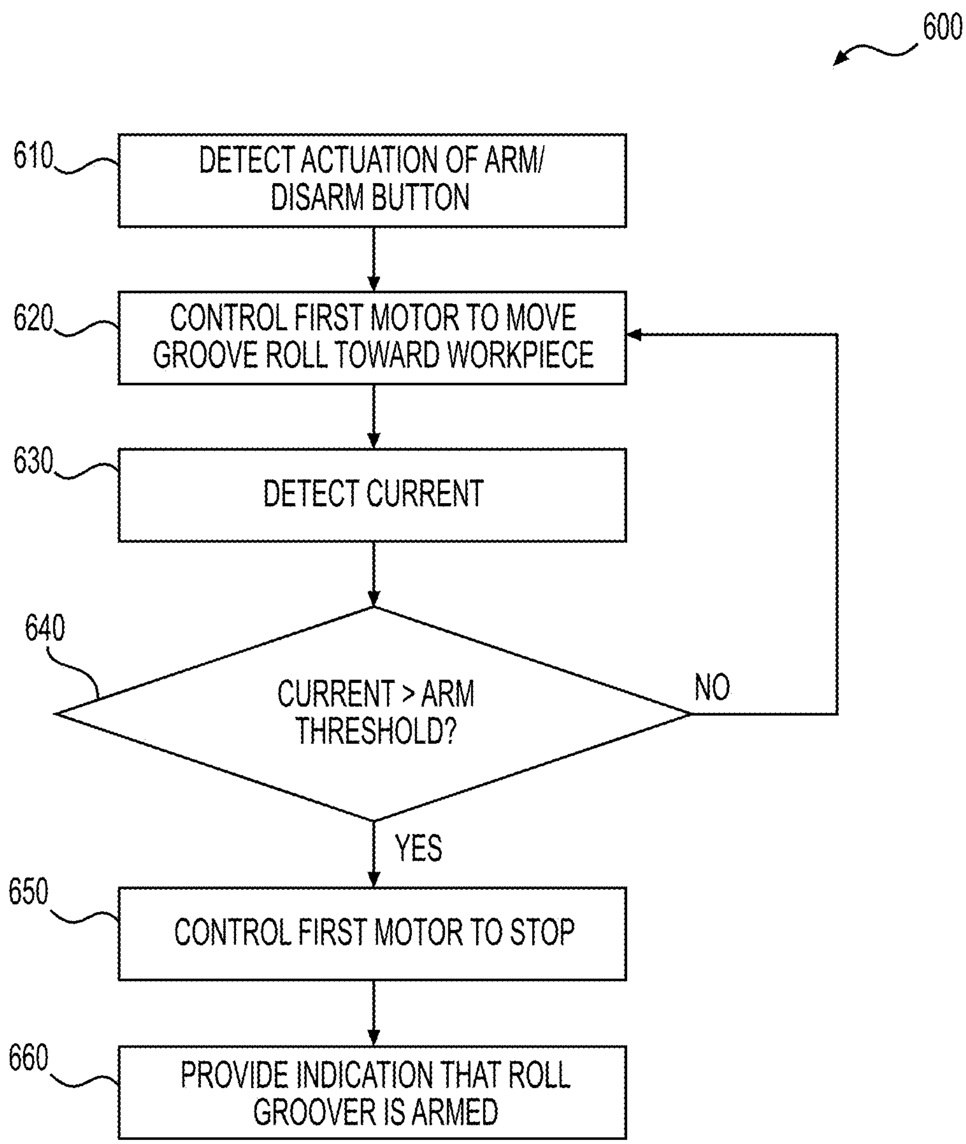
600
610
DETECT ACTUATION OF ARM/ DISARM BUTTON
620
CONTROL FIRST MOTOR TO MOVE GROOVE ROLL TOWARD WORKPIECE
630
DETECT CURRENT
640
CURRENT > ARM THRESHOLD?
NO
YES
650
CONTROL FIRST MOTOR TO STOP
660
PROVIDE INDICATION THAT ROLL GROOVER IS ARMED

FIG. 6

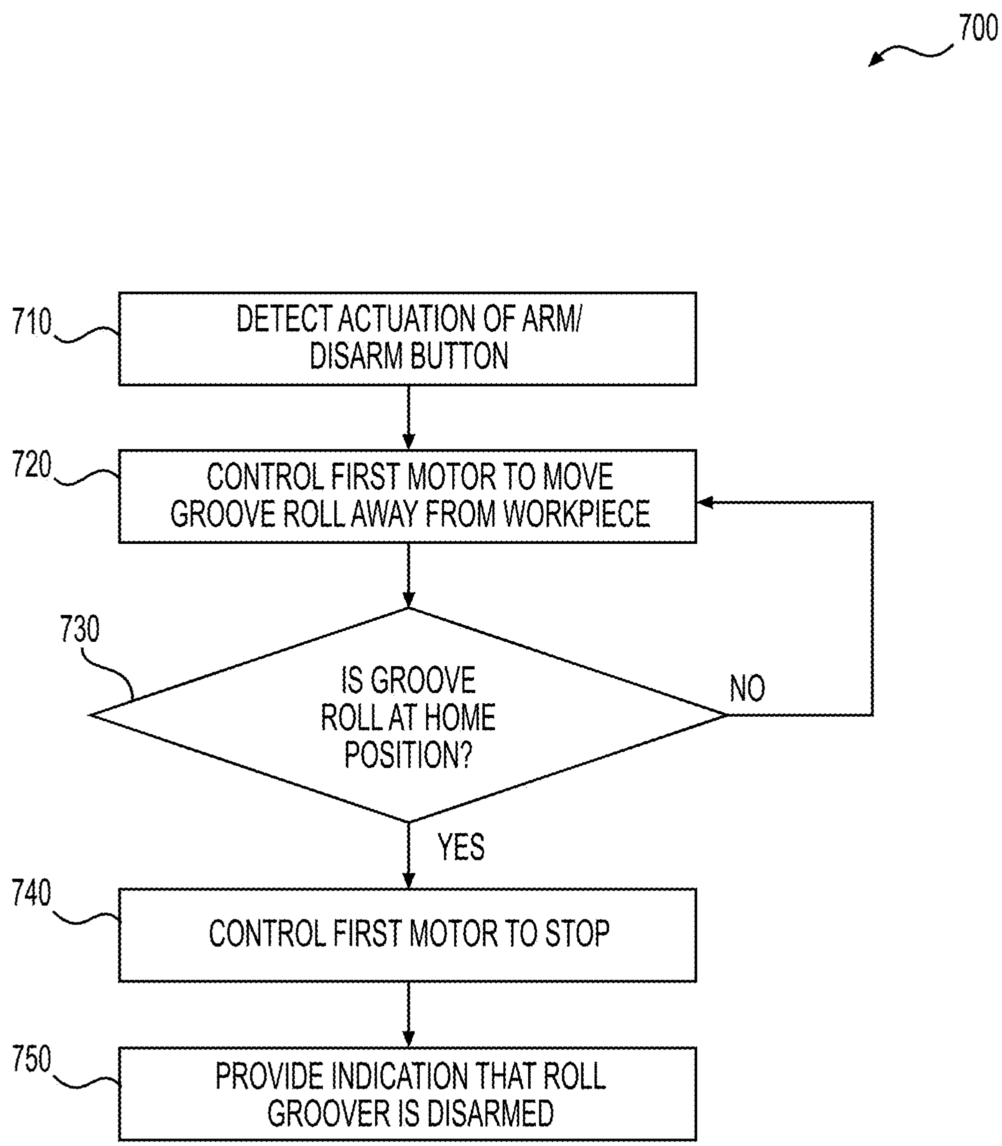
700
710
DETECT ACTUATION OF ARM/ DISARM BUTTON
720
CONTROL FIRST MOTOR TO MOVE GROOVE ROLL AWAY FROM WORKPIECE
730
IS GROOVE ROLL AT HOME POSITION?
NO
YES
740
CONTROL FIRST MOTOR TO STOP
750
PROVIDE INDICATION THAT ROLL GROOVER IS DISARMED

FIG. 7

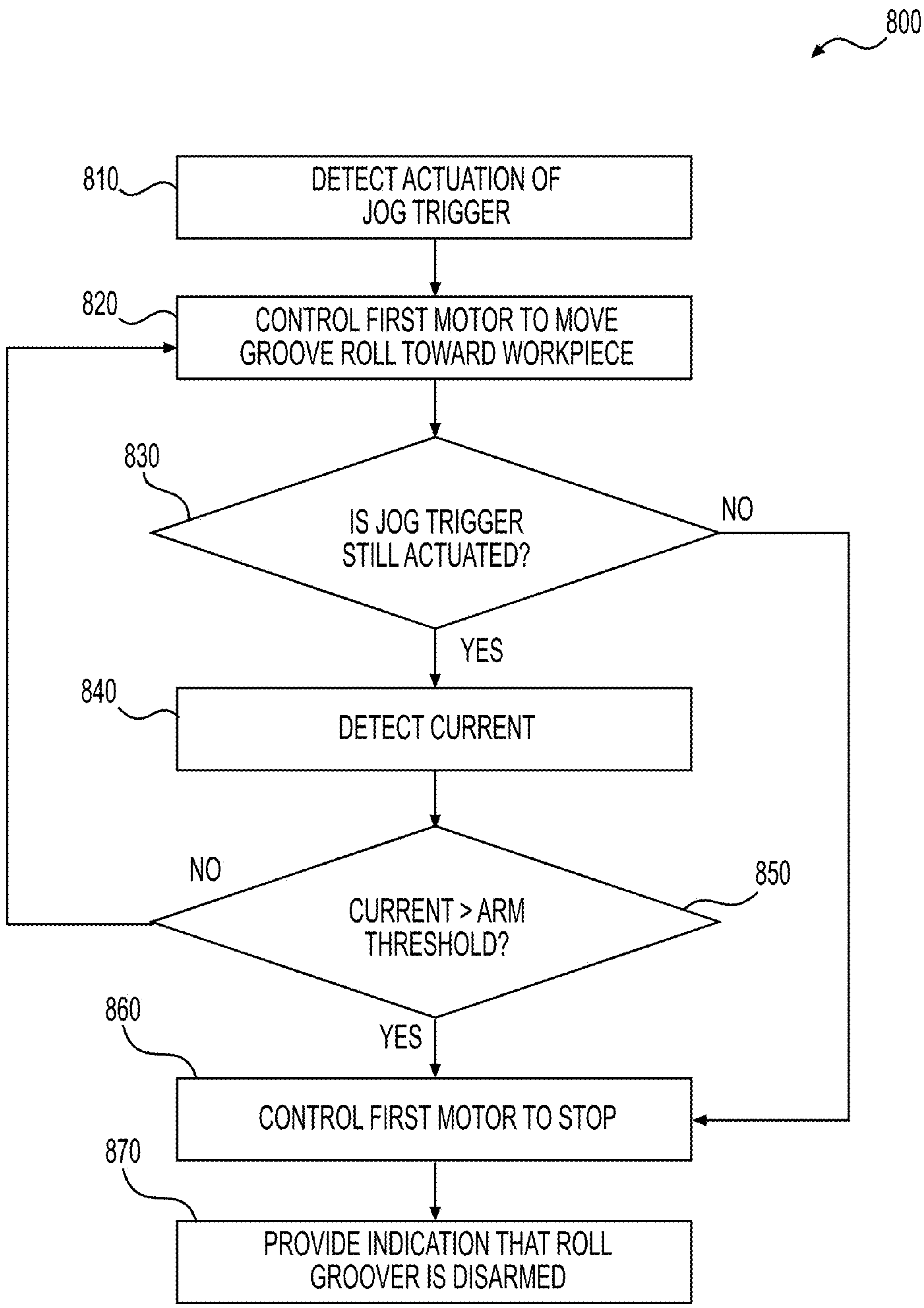
800
810
DETECT ACTUATION OF JOG TRIGGER
820
CONTROL FIRST MOTOR TO MOVE GROOVE ROLL TOWARD WORKPIECE
830
IS JOG TRIGGER STILL ACTUATED?
NO
YES
840
DETECT CURRENT
NO
850
CURRENT > ARM THRESHOLD?
YES
860
CONTROL FIRST MOTOR TO STOP
870
PROVIDE INDICATION THAT ROLL GROOVER IS DISARMED

FIG. 8

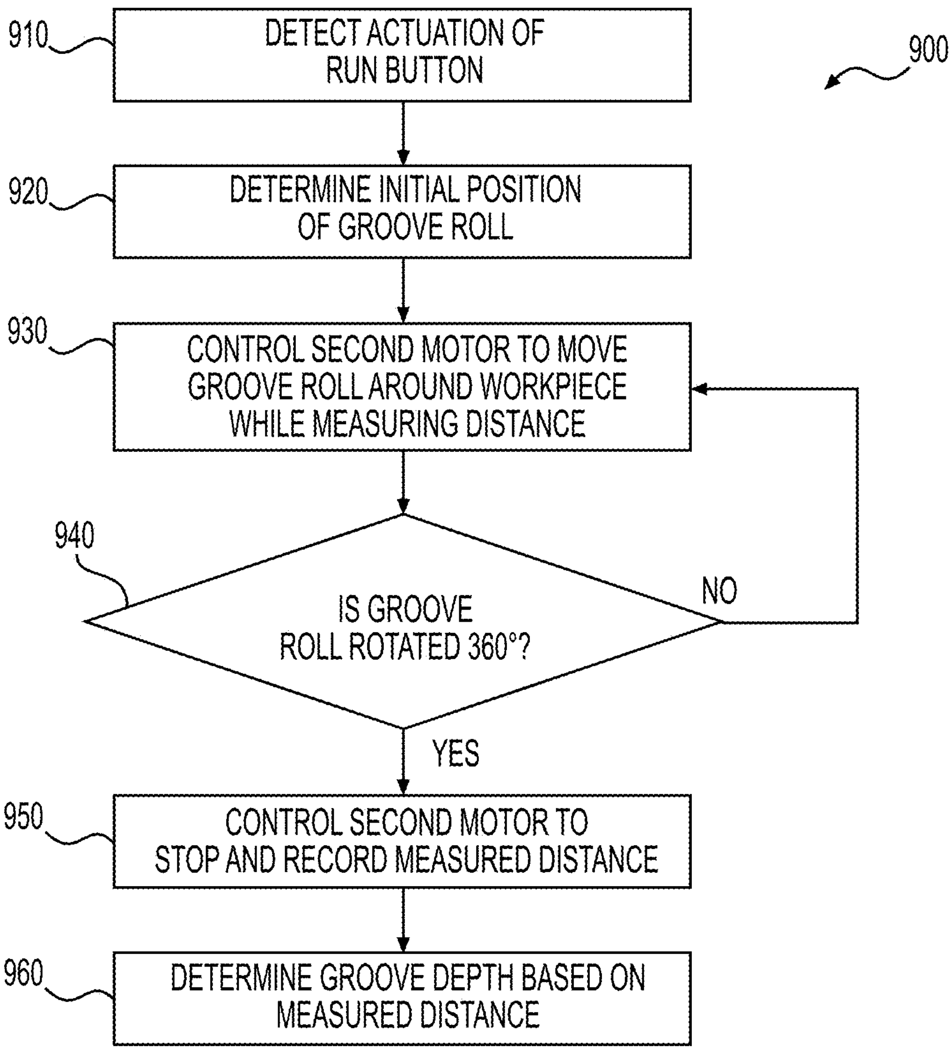
900
910
DETECT ACTUATION OF RUN BUTTON
920
DETERMINE INITIAL POSITION OF GROOVE ROLL
930
CONTROL SECOND MOTOR TO MOVE GROOVE ROLL AROUND WORKPIECE WHILE MEASURING DISTANCE
940
IS GROOVE ROLL ROTATED 360°?
NO
YES
950
CONTROL SECOND MOTOR TO STOP AND RECORD MEASURED DISTANCE
960
DETERMINE GROOVE DEPTH BASED ON MEASURED DISTANCE

FIG. 9

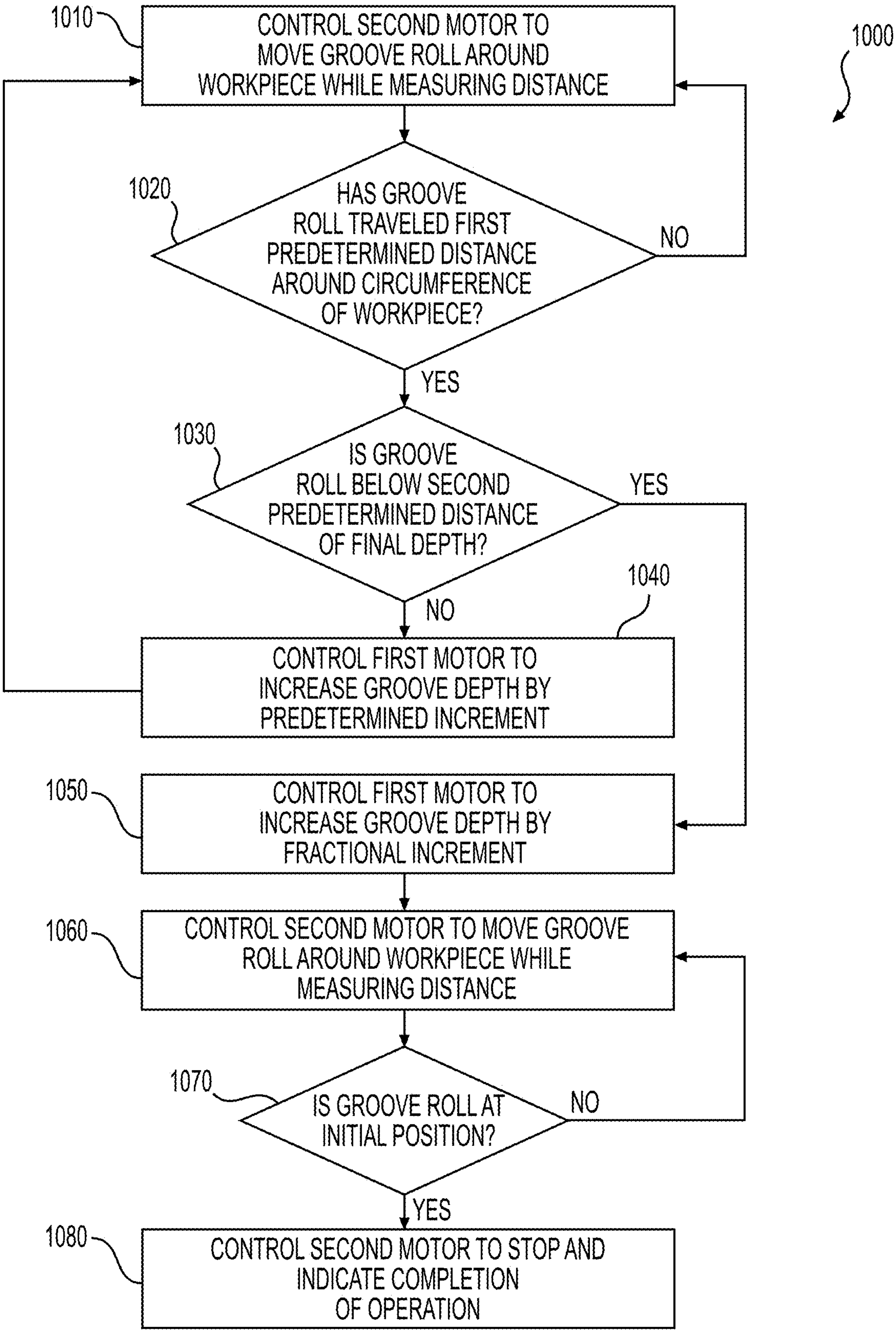
1000
1010
CONTROL SECOND MOTOR TO MOVE GROOVE ROLL AROUND WORKPIECE WHILE MEASURING DISTANCE
1020
HAS GROOVE ROLL TRAVELED FIRST PREDETERMINED DISTANCE AROUND CIRCUMFERENCE OF WORKPIECE?
NO
YES
1030
IS GROOVE ROLL BELOW SECOND PREDETERMINED DISTANCE OF FINAL DEPTH?
YES
NO
1040
CONTROL FIRST MOTOR TO INCREASE GROOVE DEPTH BY PREDETERMINED INCREMENT
1050
CONTROL FIRST MOTOR TO INCREASE GROOVE DEPTH BY FRACTIONAL INCREMENT
1060
CONTROL SECOND MOTOR TO MOVE GROOVE ROLL AROUND WORKPIECE WHILE MEASURING DISTANCE
1070
IS GROOVE ROLL AT INITIAL POSITION?
NO
YES
1080
CONTROL SECOND MOTOR TO STOP AND INDICATE COMPLETION OF OPERATION

FIG. 10

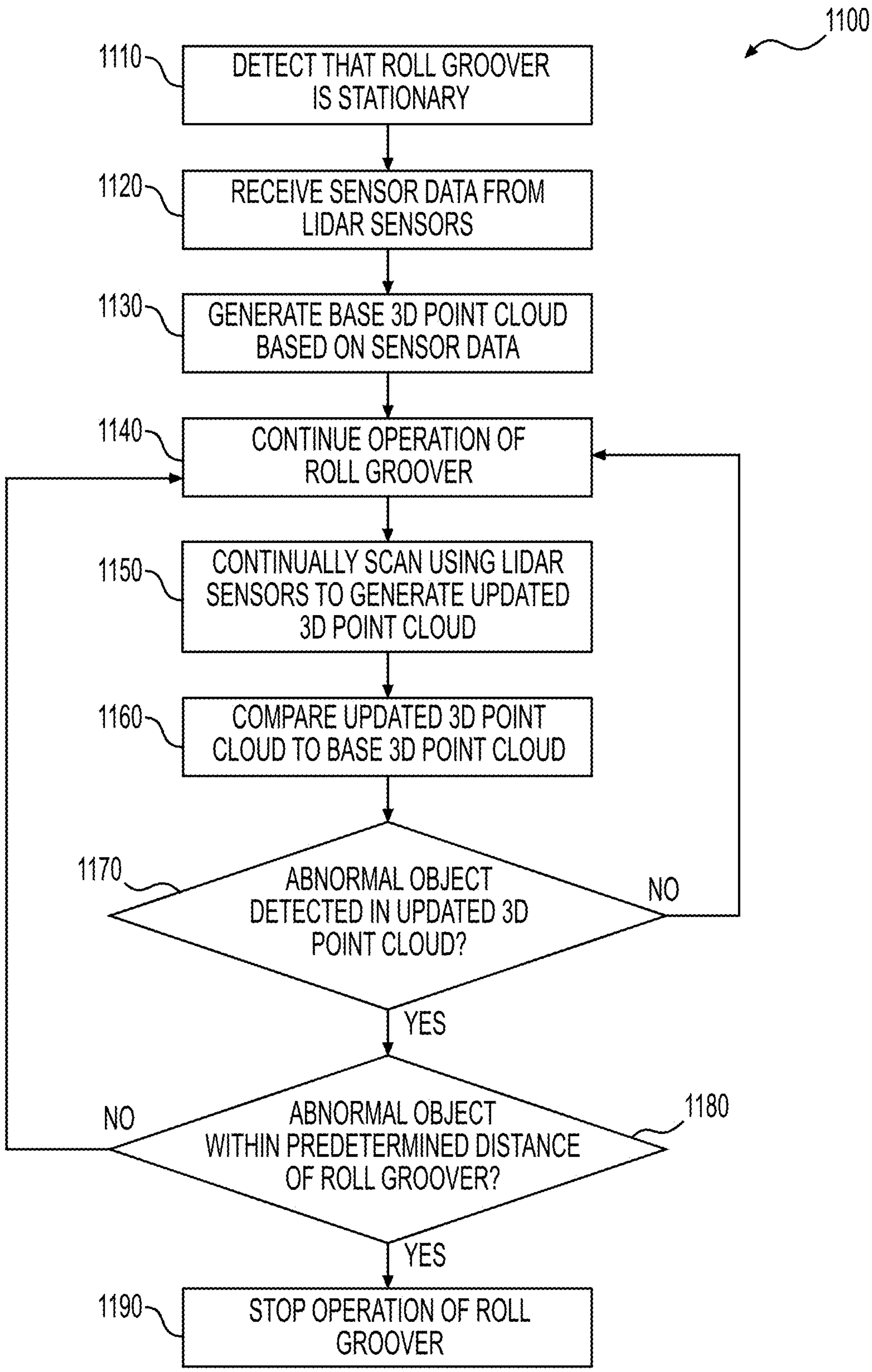
1100
1110
DETECT THAT ROLL GROOVER IS STATIONARY
1120
RECEIVE SENSOR DATA FROM LIDAR SENSORS
1130
GENERATE BASE 3D POINT CLOUD BASED ON SENSOR DATA
1140
CONTINUE OPERATION OF ROLL GROOVER
1150
CONTINUALLY SCAN USING LIDAR SENSORS TO GENERATE UPDATED 3D POINT CLOUD
1160
COMPARE UPDATED 3D POINT CLOUD TO BASE 3D POINT CLOUD
1170
ABNORMAL OBJECT DETECTED IN UPDATED 3D POINT CLOUD?
NO
YES
1180
ABNORMAL OBJECT WITHIN PREDETERMINED DISTANCE OF ROLL GROOVER?
NO
YES
1190
STOP OPERATION OF ROLL GROOVER

FIG. 11

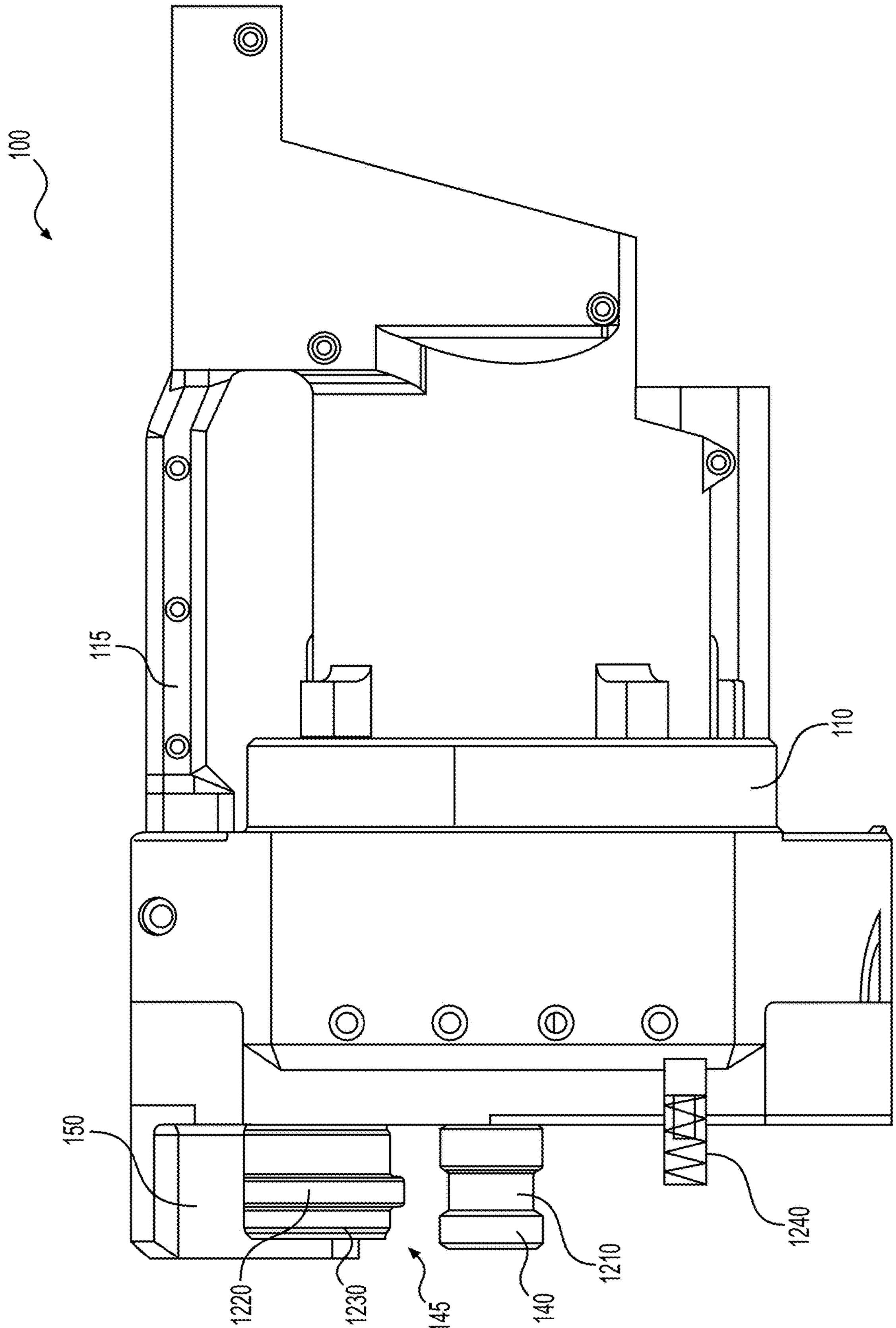

FIG. 12

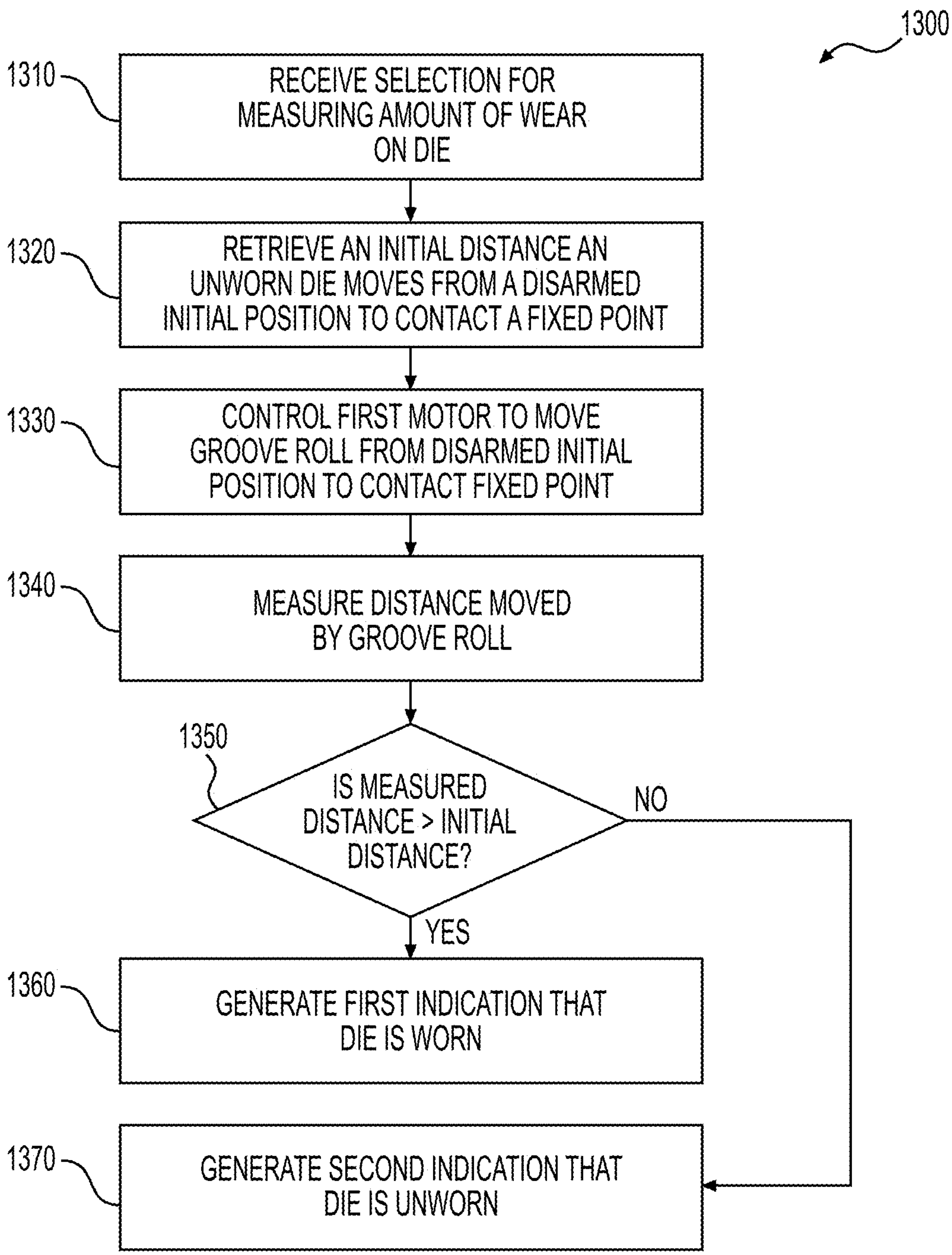
1300
1310
RECEIVE SELECTION FOR MEASURING AMOUNT OF WEAR ON DIE
1320
RETRIEVE AN INITIAL DISTANCE AN UNWORN DIE MOVES FROM A DISARMED INITIAL POSITION TO CONTACT A FIXED POINT
1330
CONTROL FIRST MOTOR TO MOVE GROOVE ROLL FROM DISARMED INITIAL POSITION TO CONTACT FIXED POINT
1340
MEASURE DISTANCE MOVED BY GROOVE ROLL
1350
IS MEASURED DISTANCE > INITIAL DISTANCE?
NO
YES
1360
GENERATE FIRST INDICATION THAT DIE IS WORN
1370
GENERATE SECOND INDICATION THAT DIE IS UNWORN

FIG. 13

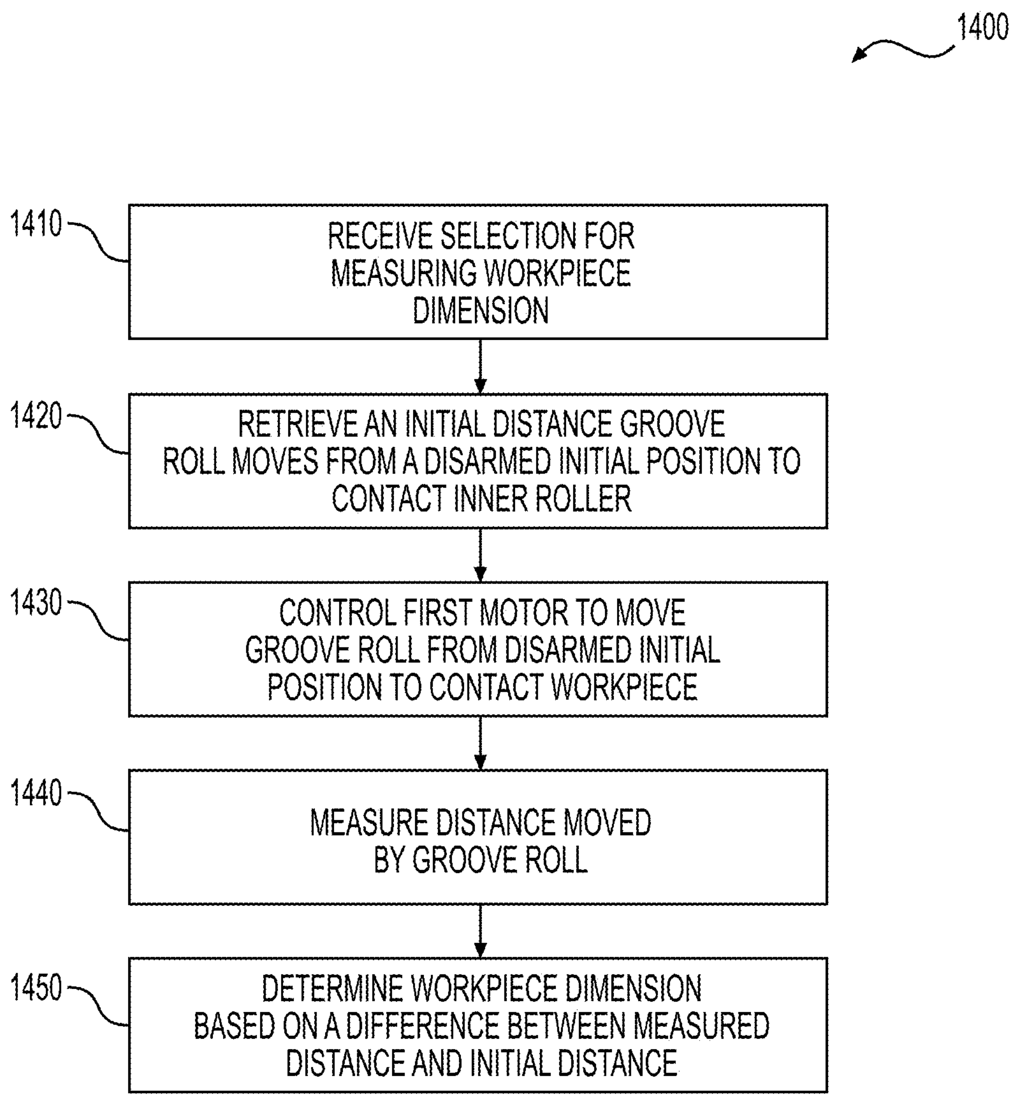
1400
1410
RECEIVE SELECTION FOR MEASURING WORKPIECE DIMENSION
1420
RETRIEVE AN INITIAL DISTANCE GROOVE ROLL MOVES FROM A DISARMED INITIAL POSITION TO CONTACT INNER ROLLER
1430
CONTROL FIRST MOTOR TO MOVE GROOVE ROLL FROM DISARMED INITIAL POSITION TO CONTACT WORKPIECE
1440
MEASURE DISTANCE MOVED BY GROOVE ROLL
1450
DETERMINE WORKPIECE DIMENSION BASED ON A DIFFERENCE BETWEEN MEASURED DISTANCE AND INITIAL DISTANCE

FIG. 14

BATTERY PACK POWERED ROLL GROOVER

RELATED APPLICATIONS

This application claims the benefit of, and priority to, U.S. patent application Ser. No. 17/505,266, filed Oct. 19, 2021, which claims the benefit of, and priority to, U.S. Provisional Patent Application No. 63/093,577, filed on Oct. 19, 2020, and U.S. Provisional Patent Application No. 63/235,507, filed on Aug. 20, 2021, the entire content of each of which are hereby incorporated by reference.

BACKGROUND

In the pipe fitting industry, different methods are used to join two separate pieces of piping together. In one example, ends of the pipes are threaded and a threaded adapter is used to join the pipes together. An alternative to a threaded connection is a grooved connection. Specifically, a pipe is cut to the desired length and a groove is rolled onto an end of the pipe. A grooved adapter is then used to join the pipe to another pipe.

SUMMARY

Grooved pipe connections are especially useful to join pipes carrying water and/or steam and to provide a water-tight seal between the pipes. A roll groover is used to produce a groove on the pipes. Roll groovers are typically mechanical devices that are placed on a pipe. A skilled user uses a crank mechanism to rotate the roll groover around the pipe to roll the groove onto the pipe. The crank mechanism involved manually rotating a crank by hand to rotate the roll groover.

Current roll groovers require skilled users to operate and take a large amount of time to complete one operation. Accordingly, there is a need for automated roll groovers that are simple to operate and reduce the operation time compared to current roll groovers.

Some embodiments provide a roll groover including a housing, an inner roller configured to be received in an inner circumference of a workpiece provided on the housing, and a groove roll configured to produce a groove on the workpiece provided on the housing. The roll groover includes a first motor to move the groove roll towards and away from the workpiece and a second motor to move the groove roll around a track and a circumference of the workpiece. The roll groover includes an electronic processor connected to the first motor and the second motor. The electronic processor is configured to operate the first motor to adjust the groove depth on the workpiece and the second motor to produce the groove on the workpiece.

Some embodiments provide a roll groover including a housing, an inner roller provided on the housing and configured to be received in an inner circumference of a workpiece, a groove roll provided on the housing and configured to produce a groove on the workpiece, one or more motors provided within the housing and configured to drive the groove roll, and an electronic processor electrically connected to the one or more motors. The electronic processor is configured to operate the one or more motors to perform a first operation of moving the groove roll in a radial direction. The first operation is performed to adjust a groove depth on the workpiece. The electronic processor is also configured to operate the one or more motors to perform a second operation of moving the groove roll in a circumferential direction. The second operation is performed to produce the groove on the workpiece.

In some aspects, the one or more motors include a first motor configured to drive the groove roll in the radial direction, and a second motor configured to drive the groove roll in the circumferential direction.

In some aspects, the roll groover also includes an inertial measurement unit configured to determine a position of the groove roll.

In some aspects, the electronic processor is also configured to control the one or more motors to move the groove roll around the workpiece while measuring a distance, and increase, using the one or more motors, groove depth in predetermined increments for each rotation of the groove roll by a first predetermined distance.

In some aspects, the roll groover also includes a battery pack configured to power the one or more motors.

In some aspects, the groove roll is provided on a circumferentially outer side of the inner roller.

In some aspects, the roll groover also includes a roll casing provided on the housing, wherein the groove roll is mounted to and moves with the roll casing. The roll casing with the groove roll moves around the track to produce the groove on the workpiece.

In some aspects, the roll groover also includes a jog trigger and a direction switch for selecting a direction of movement of the groove roll. The first operation is controlled using the jog trigger.

In some aspects, the roll groover also includes a run switch a direction switch for selecting a direction of movement of the groove roll. The second operation is controlled using the run switch.

In some aspects, the roll groover also includes one or more circuit boards provided within the housing and including electronic components of the roll groover. The one or more circuit boards includes a total surface area of less than 155 centimeters squared (cm2).

In some aspects, the electronic processor is also configured to detect an actuation of an arm/disarm button, control the one or more motors to move the groove roll toward the workpiece, detect, using one or more sensors, a current drawn by the one or more motors, determine whether the current exceeds an arm threshold, control the one or more motors to stop when the current exceeds the arm threshold, and provide an indication that the roll groover is armed.

In some aspects, the electronic processor is also configured to detect actuation of an arm/disarm button, control the one or more motors to move the groove roll away from the workpiece, determine whether the groove roll is at a home position, control the one or more motors to stop when the groove roll is at the home position, and provide an indication that the roll groover is disarmed.

In some aspects, the electronic processor is also configured to detect actuation of a jog trigger, control the one or more motors to move the groove roll toward the workpiece, and determine whether the jog trigger is still actuated. In response to the jog trigger continued to be activated, the electronic processor is configured to detect, using one or more sensors, a current drawn by the one or more motors, determine whether the current exceeds an arm threshold, control the one or more motors to stop when the current exceeds the arm threshold, and provide an indication that the roll groover is armed. In response to the jog trigger not being actuated, the electronic processor is configured to control the one or more motors to stop.

In some aspects, the electronic processor is also configured to detect actuation of a run button, determine, using an

inertial measurement unit, an initial position of the groove roll, control the one or more motors to move the groove roll around the workpiece while measuring distance, determine whether the groove roll has rotated 360°, control the one or more motors to stop and record a measured distance when the groove roll has rotated 360°, determine a groove depth based on the measured distance.

In some aspects, the electronic processor is also configured to control the one or more motors to move the groove roll around the workpiece while measuring distance, determine whether the groove roll has traveled a first predetermined distance around a circumference of the workpiece, and determine whether the groove roll is below a second predetermined distance of a final depth when the groove roll has traveled the first predetermined distance. In response to the groove roll not being below the second predetermined distance of the final depth, the electronic processor is configured to control the one or more motors to increase groove depth by a predetermined increment. In response to the groove roll being below the second predetermined distance of the final depth, the electronic processor is configured to control the one or more motors to increase groove depth by a fractional increment, control the one or more motors to move the groove roll around the workpiece, determine whether the groove roll is at an initial position, and control the one or more motors to stop and indicate completion of operation when the groove roll is at the initial position.

In some aspects, the electronic processor is also configured to receive a selection of a single revolution mode, and control the one or more motors to complete a single revolution of the groove roll around the workpiece.

In some aspects, the roll groover also includes one or more light detection and ranging (LiDAR) sensors configured to detect objects in a vicinity of the roll groover. The electronic processor is further configured to detect that the roll groover is stationary, receive sensor data from the one or more LiDAR sensors, generate a base 3D point cloud based on the sensor data, continue operation of the roll groover, continuously scan the one or more LiDAR sensors to generate an updated 3D point cloud, compare the updated 3D point cloud to the base 3D point cloud, and determine whether an abnormal object is detected in the updated 3D point cloud. In response to detecting the abnormal object, the electronic processor is configured to determine whether the abnormal object is within a predetermined distance of the roll groover, and stop operation of the roll groover when the abnormal object is within the predetermined distance of the roll groover.

In some aspects, the inner roller includes a roller groove and the groove roll includes a roller projection corresponding to the roller groove. A force exerted by the roller projection on an outer circumference of the workpiece and an allowance provided by the roller groove on the inner circumference of the workpiece together produce the groove on the workpiece.

In some aspects, the groove roll is a replaceable die.

In some aspects, the electronic processor is also configured to receive a selection for measuring an amount of wear on the replaceable die, retrieve an initial distance an unworn replaceable die moves from a disarmed initial position to contact a fixed point, control the one or more motors to move the groove roll from the disarmed initial position to the fixed point in response to receiving the selection, measure a distance moved by the groove roll when the groove roll is moved from the disarmed initial position to contact the fixed point, determine whether the measured distance is greater than the initial distance, generate a first indication that the replaceable die is worn when the measured distance is greater than the initial distance, and generate a second indication that the replaceable die is unworn when the measured distance is not greater than the initial distance.

In some aspects, the groove roll and the inner roller form a replaceable die set.

In some aspects, the electronic processor is further configured to determine identification information of the replaceable die set.

In some aspects, the electronic processor is also configured to receive a selection for measuring workpiece dimension, retrieve an initial distance the groove roll moves from a disarmed initial position to contact the workpiece, control the one or more motors to move the groove roll from the disarmed initial position to contact the workpiece in response to receiving the selection, measure a distance moved by the groove roll when the groove roll is moved from the disarmed initial position to contact the workpiece, and determine the workpiece dimension based on a difference between the measured distance and the initial distance.

In some aspects, the electronic processor is also configured to compare the workpiece dimension to an expected thickness of the workpiece, and determine that the workpiece is already grooved when the workpiece dimension is smaller than the expected thickness.

In some aspects, the roll groover also includes a limit switch provided on the housing. The electronic processor is configured to detect, using the limit switch, a walk-off of the workpiece.

In some aspects, the electronic processor is also configured to detect, using an inertial measurement unit, movement of the groove roll around the workpiece, determine a profile of the workpiece based on the movement of the groove roll around the workpiece, compare the profile of the workpiece to a predetermined profile, and determine that the workpiece is oblong when the profile of the workpiece deviates from the predetermined profile.

In some aspects, the electronic processor is also configured to detect, using a sensor, an angle of the roll groover compared to the workpiece, and determine that the workpiece is a flared pipe when the detected angle deviates from a predetermined angle.

Some embodiments provide a roll groover including a housing, an inner roller provided on the housing and configured to be received in an inner circumference of a workpiece, a groove roll provided on the housing and configured to produce a groove on the workpiece, one or more motors provided within the housing and configured to drive the groove roll, an electronic processor electrically connected to the one or more motors. The electronic processor is configured to control the one or more motors to move the groove roll around the workpiece while measuring distance, determine whether the groove roll has traveled a first predetermined distance around a circumference of the workpiece, and determine whether the groove roll is below a second predetermined distance of a final depth when the groove roll has traveled the first predetermined distance. In response to the groove roll not being below the second predetermined distance of the final depth, the electronic processor is configured to control the one or more motors to increase groove depth by a predetermined increment. In response to the groove roll being below the second predetermined distance of the final depth, the electronic processor is configured to control the one or more motors to increase groove depth by a fractional increment, control the one or more motors to move the groove roll around the workpiece, determine whether the groove roll is at an initial position, and control the one or more motors to stop and indicate completion of operation when the groove roll is at the initial position.

Some embodiments provide a method of operating a roll groover including an inner roller configured to be received in an inner circumference of a workpiece and a groove roll configured to produce a groove on the workpiece. The method includes operating, using an electronic processor, one or more motors to perform a first operation of moving the groove roll in a radial direction. The first operation is performed to adjust a groove depth on the workpiece. The method also includes operating, using the electronic processor, the one or more motors to perform a second operation of moving the groove roll in a circumferential direction. The second operation is performed to produce the groove on the workpiece.

In some aspects, the method also includes determining, using an inertial measurement unit, a position of the groove roll.

In some aspects, the method also includes controlling the one or more motors to move the groove roll around the workpiece while measuring a distance, and increasing, using the one or more motors, groove depth in predetermined increments for each rotation of the groove roll by a first predetermined distance.

In some aspects, the method also includes providing, using a battery pack, power to the one or more motors.

In some aspects, the method also includes detecting an actuation of an arm/disarm button, controlling the one or more motors to move the groove roll toward the workpiece, detecting, using one or more sensors, a current drawn by the one or more motors, determining whether the current exceeds an arm threshold, controlling the one or more motors to stop when the current exceeds the arm threshold, and providing an indication that the roll groover is armed.

In some aspects, the method also includes detecting actuation of an arm/disarm button, controlling the one or more motors to move the groove roll away from the workpiece, determining whether the groove roll is at a home position, controlling the one or more motors to stop when the groove roll is at the home position, and providing an indication that the roll groover is disarmed.

In some aspects, the method also includes detecting actuation of a jog trigger, controlling the one or more motors to move the groove roll toward the workpiece, and determining whether the jog trigger is still actuated. In response to the jog trigger continued to be activated, the method includes detecting, using one or more sensors, a current drawn by the one or more motors, determining whether the current exceeds an arm threshold, controlling the one or more motors to stop when the current exceeds the arm threshold, and providing an indication that the roll groover is armed In response to the jog trigger not being actuated the method includes controlling the one or more motors to stop.

In some aspects, the method also includes detecting actuation of a run button, determining, using an inertial measurement unit, an initial position of the groove roll, controlling the one or more motors to move the groove roll around the workpiece while measuring distance, determining whether the groove roll has rotated 360°, controlling the one or more motors to stop and record a measured distance when the groove roll has rotated 360°, and determining a groove depth based on the measured distance.

In some aspects, the method also includes controlling the one or more motors to move the groove roll around the workpiece while measuring distance, determining whether the groove roll has traveled a first predetermined distance around a circumference of the workpiece, and determining whether the groove roll is below a second predetermined distance of a final depth when the groove roll has traveled the first predetermined distance. In response to the groove roll not being below the second predetermined distance of the final depth, the method includes controlling the one or more motors to increase groove depth by a predetermined increment. In response to the groove roll being below the second predetermined distance of the final depth, the method includes controlling the one or more motors to increase groove depth by a fractional increment, controlling the one or more motors to move the groove roll around the workpiece, determining whether the groove roll is at an initial position, and controlling the one or more motors to stop and indicate completion of operation when the groove roll is at the initial position.

In some aspects, the method also includes receiving a selection of a single revolution mode, and controlling the one or more motors to complete a single revolution of the groove roll around the workpiece.

In some aspects, the method also includes detecting that the roll groover is stationary, receiving sensor data from one or more light detection and ranging (LiDAR) sensors, generating a base 3D point cloud based on the sensor data, continuing operation of the roll groover, continuously scanning the one or more LiDAR sensors to generate an updated 3D point cloud, comparing the updated 3D point cloud to the base 3D point cloud, and determining whether an abnormal object is detected in the updated 3D point cloud. In response to detecting the abnormal object, the method includes determining whether the abnormal object is within a predetermined distance of the roll groover, and stopping operation of the roll groover when the abnormal object is within the predetermined distance of the roll groover.

In some aspects, the groove roll is a replaceable die and the method includes receiving a selection for measuring n amount of wear on the replaceable die, retrieving an initial distance an unworn replaceable die moves from a disarmed initial position to contact a fixed point, controlling the one or more motors to move the groove roll from the disarmed initial position to the fixed point in response to receiving the selection, measuring a distance moved by the groove roll when the groove roll is moved from the disarmed initial position to contact the fixed point, determining whether the measured distance is greater than the initial distance, generating a first indication that the replaceable die is worn when the measured distance is greater than the initial distance, and generating a second indication that the replaceable die is unworn when the measured distance is not greater than the initial distance.

In some aspects, the method also includes receiving a selection for measuring workpiece dimension, retrieving an initial distance the groove roll moves from a disarmed initial position to contact the workpiece, controlling the one or more motors to move the groove roll from the disarmed initial position to contact the workpiece in response to receiving the selection, measuring a distance moved by the groove roll when the groove roll is moved from the disarmed initial position to contact the workpiece, and determining the workpiece dimension based on a difference between the measured distance and the initial distance.

In some aspects, the method also includes comparing the workpiece dimension to an expected thickness of the workpiece, and determining that the workpiece is already grooved when the workpiece dimension is smaller than the expected thickness.

In some aspects, the method also includes detecting, using a limit switch, a walk-off of the workpiece.

In some aspects, the method also includes detecting, using an inertial measurement unit, movement of the groove roll around the workpiece, determining a profile of the workpiece based on the movement of the groove roll around the workpiece, comparing the profile of the workpiece to a predetermined profile, and determining that the workpiece is oblong when the profile of the workpiece deviates from the predetermined profile.

In some aspects, the method also includes detecting, using a sensor, an angle of the roll groover compared to the workpiece, and determining that the workpiece is a flared pipe when the detected angle deviates from a predetermined angle.

Some embodiments provide a method of operating a roll groover including an inner roller configured to be received in an inner circumference of a workpiece and a groove roll configured to produce a groove on the workpiece. The method includes controlling one or more motors to move the groove roll around the workpiece while measuring distance, determining whether the groove roll has traveled a first predetermined distance around a circumference of the workpiece, and determining whether the groove roll is below a second predetermined distance of a final depth when the groove roll has traveled the first predetermined distance. In response to the groove roll not being below the second predetermined distance of the final depth, the method includes controlling the one or more motors to increase groove depth by a predetermined increment. In response to the groove roll being below the second predetermined distance of the final depth, the method includes controlling the one or more motors to increase groove depth by a fractional increment, controlling the one or more motors to move the groove roll around the workpiece, determining whether the groove roll is at an initial position, and controlling the one or more motors to stop and indicate completion of operation when the groove roll is at the initial position.

Before any embodiments are explained in detail, it is to be understood that the embodiments are not limited in its 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.

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 embodiment, 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," "computing devices," "controllers," "processors," etc., 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.

Relative terminology, such as, for example, "about," "approximately," "substantially," etc., used in connection with a quantity or condition would be understood by those of ordinary skill to be inclusive of the stated value and has the meaning dictated by the context (e.g., the term includes at least the degree of error associated with the measurement accuracy, tolerances [e.g., manufacturing, assembly, use, etc.] associated with the particular value, etc.). Such terminology should also be considered as disclosing the range defined by the absolute values of the two endpoints. For example, the expression "from about 2 to about 4" also discloses the range "from 2 to 4". The relative terminology may refer to plus or minus a percentage (e.g., 1%, 5%, 10%, or more) of an indicated value.

It should be understood that although certain drawings illustrate hardware and software located within particular devices, these depictions are for illustrative purposes only. Functionality described herein as being performed by one component may be performed by multiple components in a distributed manner. Likewise, functionality performed by multiple components may be consolidated and performed by a single component. In some embodiments, the illustrated components may be combined or divided into separate software, firmware and/or hardware. For example, instead of being located within and performed by a single electronic processor, logic and processing may be distributed among multiple electronic processors. Regardless of how they are combined or divided, hardware and software components may be located on the same computing device or may be distributed among different computing devices connected by one or more networks or other suitable communication links. Similarly, a component described as performing particular functionality may also perform additional functionality not described herein. For example, a device or structure that is "configured" in a certain way is configured in at least that way but may also be configured in ways that are not explicitly listed.

Other aspects of the embodiments will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of roll groover operating on a workpiece in accordance with some embodiments.

FIG. **2** is a plan view of the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **3A-3C** are block diagrams of the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **4** is a block diagram of an external device communicating with the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **5** is a flowchart of a method for detecting a position of the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **6** is a flowchart of a method for arming the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **7** is a flowchart of a method for disarming the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **8** is a flowchart of a method for arming the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **9** is a flowchart of a method for determining groove depth of a workpiece using the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **10** is a flowchart of a method for operating the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **11** is a flowchart of a method for entanglement awareness of the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **12** is a side perspective view of the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **13** is a flowchart of a method for measuring an amount of die wear of the roll groover of FIG. **1** in accordance with some embodiments.

FIG. **14** is a flowchart of a method for measuring a workpiece dimension using the roll groover of FIG. **1** in accordance with some embodiments.

DETAILED DESCRIPTION

FIGS. **1** and **2** illustrate an example embodiment of a roll groover **100**. The roll groover **100** is configured to operate on a workpiece **105**, for example, a metal pipe, or the like. The roll groover **100** includes a housing **110** and a handle **115** that forms part of the housing. The roll groover **100** also includes a jog trigger **120** and a run switch **125**. In some embodiments, the roll groover **100** may include an arm/disarm button **120** in place of or in addition to the jog trigger **120**. In the example illustrated, the roll groover **100** is powered by a battery pack **130**. The battery pack **130** is, for example, a power tool battery pack having a nominal voltage of 12 V, 18 V, 36 V, 60 V, 80 V, or the like. In some embodiments, the roll groover **100** may be powered by an AC power source and may include a power cord that can be plugged into a wall outlet.

The roll groover **100** includes an inner roller **140** provided around a center of the housing **110**. The inner roller **140** is received on the inside of a pipe. The inner roller **140** is dimensioned to fit within the inner circumference of any pipe currently used in the industry for transporting water and steam. A groove roll **145** is provided on a circumferentially outer side of the inner roller **140**. The groove roll **145** engages an outer circumference of the workpiece **105** to roll a groove onto the workpiece **105**. A roll casing **150** is provided over the groove roll **145** such that the groove roll **145** is mounted and moves with the roll casing **150**. The roll casing **150** with the groove roll **145** moves around a track **155**. The groove roll **145** produces a groove on the workpiece **105** by moving around the track **155**.

FIG. **3**A illustrates a block diagram of the roll groover **100**. In the example illustrated, the roll groover **100** includes a controller (for example, an electronic processor **200**) electrically and/or communicatively connected to a variety of modules or components of the roll groover **100**. For example, the illustrated electronic processor **200** is connected to a battery pack interface **205**, a power input module **210**, a FET switching module **215**, one or more sensors **220**, a transceiver **230**, a user input module **235**, one or more indicators **240**, the jog trigger **120** (or the arm/disarm button **120**), and the run switch **125**. The electronic processor **200** includes combinations of hardware and software that are operable to, among other things, control operation of the roll groover **100**, activate one or more indicators **240**, monitor the operation of the roll groover **100**, communicate with an associated external device (e.g., a smartphone) and the like.

In some embodiments, the electronic processor **200** includes a plurality of electrical and electronic components that provide power, operational control, and protection to the components and modules within the electronic processor **200** and/or the roll groover **100**. For example, the electronic processor **200** includes, among other things, a processing unit **250** (e.g., a microprocessor, a microcontroller, an electronic processor, or another suitable programmable device), a memory **255**, input units **260**, and output units **265**. The processing unit **250** includes, among other things, a control unit **270**, an arithmetic logic unit ("ALU") **275**, and a plurality of registers **280** (shows as a group of registers in FIG. **3**A), and is implemented using a known computer architecture, such as a modified Harvard architecture, a von Neumann architecture, etc. The processing unit **250**, the memory **255**, the input units **260**, and the output units **265** as well as the various modules connected to the electronic processor **200** are connected by one or more control and/or data buses (e.g., a common bus **285**). The control and/or data buses are shown generally in FIG. **3**A 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 invention described herein.

The memory **255** 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 read-only memory ("ROM"), random access memory ("RAM") (e.g., dynamic RAM ["DRAM"], synchronous DRAM ["SDRAM"], etc.), electrically erasable programmable read-only memory ("EEPROM"), flash memory, a hard disk, an SD card, or other suitable magnetic, optical, physical, or electronic memory devices. The processing unit **250** is connected to the memory **255** and executes software instructions that are capable of being stored in a RAM of the memory **255** (e.g., during execution), a ROM of the memory **255** (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 roll groover **100** can be stored in the memory **255** of the electronic processor **200**. The software includes, for example, firmware, one or more applications, program data, filters, rules, one or more program modules, and other executable instructions. The electronic processor **200** is configured to retrieve from memory and execute, among other things, instructions related to the control processes and methods described herein. In other constructions, the electronic processor **200** includes additional, fewer, or different components.

The battery pack interface **205** includes a combination of mechanical and electrical components configured to and operable for interfacing with the battery pack **130**. For example, power provided by the battery pack **130** to the roll groover **100**, is provided through the battery pack interface to a power input module **210**. The power input module **210** includes combinations of active and passive components to regulate or control the power received from the battery pack **130** prior to power being provided to the electronic processor **200**. The battery pack interface **205** also supplies power to the FET switching module **215** to be switched by switching FETs in the FET switching module **215** to selectively provide power to a first motor **290** and a second motor **295**. In some embodiments, the roll groover includes multiple independent FET switching bridges (e.g., including six FETs) in the FET switching module **215**. The battery pack interface **205** also includes, for example, a communication line **296** for providing a communication line or link between the electronic processor **200** and the battery pack **130**.

The first motor **290** and the second motor **295** are, for example, brushless direct current (BLDC) motors. The first motor **290** is operated to move the groove roll **145** radially inward and outward. The first motor **290** is controlled by the user using the jog trigger **120** (or arm/disarm button **120**). The jog trigger **120** may be implemented as a trigger switch, a push button, a knob, or the like. When the user actuates the jog trigger **120**, the electronic processor **200** controls the FET switching module **215** to move the groove roll **145** radially inward or radially outward. The first motor **290** is coupled to the groove roll **145** using, for example, a feed-screw. The first motor **290** drives the feedscrew to produce movement in the groove roll **145**. The FET switching module **215** includes a first H-bridge or a first inverter bridge used for controlling the first motor **290**. The electronic processor **200** provides PWM signals to the first H-bridge or the first inverter bridge to control the speed and direction of the first motor **290** based on signals received from the jog trigger **120** and a first rotary encoder **310** (shown in FIG. **3**B). The direction of movement, that is, radially inward or radially outward, may be selected using a direction switch provided separately from the jog trigger **120**. When the groove roll **145** is moved radially inward toward the inner roller **140**, the groove roll **145** engages the workpiece **105** to bite into the workpiece **105**. The jog trigger **120** may be operated until the groove roll **145** engages the workpiece as further described below with respect to FIGS. **6** and **8**. When the groove roll **145** is moved radially outward away from the inner roller **140**, the groove roll **145** disengages the work-piece **105** such that the roll groover **100** can be removed from the workpiece **105**. In some embodiments, the first motor **290** moves the inner roller **140** rather than the groove roll **145**.

The second motor **295** is operated to move the roll casing **150** and the groove roll **145** circumferentially around the workpiece **105** to generate the groove in the workpiece **105**. That is, the roll groover **100** or a portion of the roll groover **100** (e.g., the groove roll **145**) moves around the pipe rather than the pipe turning within the tool. The second motor **245** is controlled by the user using the run switch **125**. The run switch **125** may be implemented as a trigger switch, a push button, a knob, or the like. When the user actuates the run switch **125**, the electronic processor **200** controls the FET switching module **215** to move the roll casing **150** and the groove roll **145** around the track **155**. The FET switching module **215** includes a second H-bridge or a second inverter bridge used for controlling the second motor **295**. The controller **200** provides PWM signals to the second H-bridge or the second inverter bridge to control the speed and direction of the second motor **295** based on the signals received from the run switch **125** and a second rotary encoder **320** (shown in FIG. **3**B). The direction of movement, that is, clockwise or anti-clockwise, may be selected using a direction switch provided separately from the run switch **125**. The second motor **295** may move the roll casing **150** and the groove roll **145** in either direction to produce the groove in the workpiece **105**. In some embodiments, a single motor rather than the first motor **290** and the second motor **295** may be used to control both the radial movement and the circumferential movement of the groove roll **145**. This can be achieved by using mechanical gears and clutching to shift the operation of the single motor between the different movements.

In some embodiments, several of the electrical components of the roll groover **100** are provided on one or more circuit boards. The circuit boards may, for example, be associated with the motors **290**, **295**, the jog trigger **120**, the run switch **125**, the on/off button **236**, the direction switch **237**, and the battery pack interface **205**. The one or more circuit board include a total surface area less than 155 squared centimeters (cm^2) (24 in^2). Specifically, the total surface are covered by the one or more circuit board includes electronic components for control of two motors **290**, **295**.

Referring to FIG. **3**B, the one or more sensors **220** includes a first rotary encoder **310**, a second rotary encoder **320**, and a plurality of LiDAR (light detection and ranging) sensors **330**. The first rotary encoder **310** and the second rotary encoder **320** are, for example, hall-effect sensors. The first rotary encoder **310** is provided on the first motor **290** to detect a rotary position of the first motor **290**. The first rotary encoder **310** includes, for example, three Hall-effect sensors placed 120 degrees apart. The first rotary encoder **310** divides the motor into six sectors (for example, 0-60°, 60-120°, 120-180°, 180-240°, 240-300°, 300-360°). A full mechanical rotation of the rotor includes movement of the rotor through these six sectors twice. Specifically, power flows through the six sectors to produce a force on the rotor to rotate the rotor within a stator. Thus, the rotary position of the rotor of the first motor **290** can be accurately sensed for every 12^{th} of the circumference of the rotor. Addition Hall-effect sensors may be used to provide more granular measurements. Through the coupling of the rotor to a gearcase and a feedscrew, a linear equation directly ties the rotation of the rotor to the linear movement of the feedscrew. The rotary position of the motor and the linear equation can be used to accurately detect the linear position of the groove roll **145** and produce incremental movement of the groove roll **145**.

The second rotary encoder **320** is provided on the second motor **295** to detect a rotary position of the second motor **295**. The second rotary encoder **320** includes, for example, three Hall-effect sensors placed 120 degrees apart. The second rotary encoder **320** divides the motor into six sectors (for example, 0-60°, 60-120°, 120-180°, 180-240°, 240-300°, 300-360°). A full mechanical rotation of the rotor includes movement of the rotor through these six sectors twice. Specifically, power flows through the six sectors to produce a force on the rotor to rotate the rotor within a stator. Thus, the rotary position of the rotor of the second motor **295** can be accurately sensed for every 12^{th} of the circumference of the rotor. Additional Hall-effect sensors may be used to provide more granular measurements. Through the coupling of the rotor to a gearcase and the groove roll **145**, a linear equation directly ties the rotation of the rotor to the rotational movement of the groove roll **145** around the track **155**. The rotary position of the motor and the linear equation can be used to accurately detect the rotational position of the groove roll **145** and produce movement of the groove roll **145** around the circumferential track **155**.

The plurality of LiDAR sensors **330** are used to detect objects in the vicinity of the roll groover **100**. During automated operation of the roll groover **100**, the LiDAR sensors **330** may be used to detect obstructions or objects in the vicinity of the roll groover **100**. An example method for detecting objects in the vicinity of the roll groover **100** is explained below with respect to FIG. **11**. The one or more sensors **220** may include additional sensors, for example, a current sensor, a voltage sensor, and the like.

The inertial measurement unit **225** is operably coupled to the electronic processor **200** to, for example, provide heading, orientation, location, and movement information of the roll groover **100** to the electronic processor **200**. Referring to FIG. **3**C, the inertial measurement unit **225** includes, for example, a 9-axis inertial measurement sensor including a gyroscope **340**, an accelerometer **350**, and a magnetometer **360**. The gyroscope **340** provides an orientation of the roll groover **100**, the accelerometer **350** provides an angular position/velocity and a gravitational pull acceleration of the roll groover **100**, and the magnetometer **360** provides a heading of the roll groover **100**. The electronic processor **200** uses the information received from the inertial measurement unit **225** to determine a position and/or orientation of the roll groover **100**. A method for determining the position of the roll groover **100** is explained below with respect to FIG. **5**.

Referring back to FIG. **3**A, the transceiver **230** is operably coupled to the electronic processor **200** to, for example, allow wired and/or wireless communication with an external device **400** (shown in FIG. **4**) (e.g., a user's smartphone, a connected display or control unit, and the like). The transceiver **230** allows the electronic processor **200** to receive inputs from the external device and provide outputs for display on the external device. In some embodiments, the jog trigger **120**, the run switch **125**, the indicators **240**, and the user input module **235** may be implemented as inputs and/or outputs on the external device. The inputs from the external device **400** are received through the transceiver **230** and the outputs to the external device **400** are provided through the transceiver **230**.

The user input module **235** is operably coupled to the electronic processor **200** to, for example, select a direction of operation, a torque, and/or speed setting of the first motor **290** and/or the second motor **295**. For example, the user input module **235** includes an ON/OFF switch **236** to turn the roll groover **100** on or off and a direction switch **237** to select a direction of rotation of the groove roll **145**. In some embodiments, the user input module **235** includes a combination of digital and analog input or output devices required to achieve a desired level of operation for the roll groover **100**, such as one or more knobs, one or more dials, one or more switches, one or more buttons, a touch screen, etc. In some embodiments, the jog trigger **120** and the run switch **125** are part of the user input module **235**. The indicators **240** include, for example, one or more light-emitting diodes ("LED"). The indicators **240** can be configured to display conditions of, or information associated with the roll groover **100**. For example, the indicators **240** are configured to indicate that the groove roll **145** has reached a selected depth, the roll grooving operation is complete, and the like. In some embodiments, the indicators **240** may be part of a connected display or may be provided in an external device.

FIG. **4** illustrates a block diagram of an example embodiment of an external device **300** communicating with the roll groover **100**. The external device **400** is, for example, a smart telephone, a smart wearable device, a tablet computer, a laptop computer, a remote control unit, and the like. In the example illustrated, the external device **400** includes a device electronic processor **410**, a device memory **420**, a device transceiver **430**, and a device input/output interface **440**. The device electronic processor **410**, the device memory **420**, the device transceiver **430**, and the device input/output interface **440** communicate over one or more control and/or data buses (e.g., device communication bus **450**). The device electronic processor **410** and the device memory **420** are implemented similar to the processing unit **250** and the memory **255**, respectively. The device memory **420** stores a roll groover application **460** that is executed by the device electronic processor **410** to perform functions of the external device **400** described herein.

The device transceiver **430** allows for wired or wireless communication with the roll groover **100**. The device transceiver **430** may include separate receiving and transmitting components, for example, a receive and a transmitter. The device input/output interface **440** includes one or more input units (e.g., a mouse, a keyboard, a touch pad, and the like), one or more output units (e.g., a display, a speaker, indicators, and the like), and/or combination input/output units (e.g., a touch screen). The device input/output interface **440** may generate a graphical user interface (GUI) on a display of the external device **400** to receive various inputs (e.g., jog trigger, run switch, direction of motors, and the like) and to display various outputs (e.g., job completion, error warnings, and the like).

FIG. **5** is a flowchart of an example method **500** for determining a position of the roll groover **100**. The method **500** includes receiving, at the electronic processor, a heading of the roll groover **100** from the magnetometer **360** (at block **510**), an angular or gravitational pull acceleration from the accelerometer **350** (at block **520**), and an orientation from the gyroscope **340** (at block **530**). The electronic processor **200** receives the heading, the angular or gravitational pull acceleration, and the orientation from the inertial measurement unit **225**.

The method **500** also includes applying, using the electronic processor **200**, a zero velocity filter (at block **540**). The zero velocity filter removes any interfering signals between the inputs. The method **500** includes doubly integrating, using the electronic processor **200**, the result (at block **550**) after applying the zero velocity filter. Doubly integrating the result provides an estimated position of the roll groover **100**. The method **500** includes applying, using the electronic processor **200**, a standard complementary filter (at block **560**). Over time, error may build up in the sensor readings. The standard complementary filter corrects the error to improve the accuracy of the sensor readings. The method **500** includes reporting, using the electronic processor, the position of the roll groover **100** (at block **570**). The roll groover **100** position is used for operation of the roll groover **100** as described below with respect to FIG. **9**.

FIG. **6** is a flowchart of an example method **600** for arming the roll groover **100**. The method **600** includes detecting, using the electronic processor **200**, actuation of the arm/disarm button **120** (at block **610**). The user places the roll groover **100** on the workpiece **105** (for example, a metal pipe). The roll groover **100** is placed such that the inner roller **140** is received in the inner circumference of the pipe. The inner roller **140** supports the roll groover **100** on the workpiece **105**. The user may then actuate the arm/disarm button **120** to arm the roll groover **100** onto the workpiece **105**. The arm/disarm button **120** may be provided on the housing of the roll groover **100**, on a connected display, or the external device **400**.

The method **600** includes controlling, using the electronic processor **200**, the first motor **290** to move the groove roll **145** toward the workpiece **105** (at block **620**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The first motor **290** is controlled to move the groove roll **145** towards the inner roller **140**. In some embodiments, the first motor **290** is used to move the inner roller **140** rather than the groove roll **145** to move the groove roll **145** toward the workpiece **105**.

The method **600** includes detecting, using the one or more sensors **220**, a current drawn by the first motor **290** (at block **630**). The one or more sensors **220** may include, for example, a current sensor that detects an amount of current flowing to the first motor **290**. The current sensor provides a signal indicating the amount of current drawn by the first motor **290** to the electronic processor **200**.

The method **600** includes determining, using the electronic processor **200**, whether the current exceeds an arm threshold of the roll groover **100** (at block **640**). During operation of the first motor **290**, the current flow is typically constant when the groove roll **145** does not encounter resistance. When the groove roll **145** contacts the workpiece **105**, the current drawn by the first motor **290** starts increasing. An accumulator may be used to accumulate the current signals and detect a sudden increase in current. The electronic processor **200** determines that the groove roll **145** has contacted the workpiece **105** when the current accumulator reaches the predetermined arm threshold value.

The electronic processor **200** continues operation of the first motor **290** when the current does not exceed the arm threshold. When the current exceeds the arm threshold, the method **600** includes controlling, using the electronic processor **200**, the first motor **290** to stop (at block **650**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The method **600** includes providing, using the electronic processor **200**, an indication that the roll groover **100** is armed (at block **660**). The electronic processor **200** activates an indicator **240** (for example, an LED) to inform the user that the roll groover **100** is armed. Once the roll groover **100** is armed, the roll groover **100** can support itself on the workpiece **105**. The user may then remove their hand(s) from the roll groover **100**.

FIG. **7** is a flowchart of an example method **700** for disarming the roll groover **100**. The method **700** includes detecting, using the electronic processor **200**, actuation of the arm/disarm button **120** (at block **710**). Once the roll groover **100** has completed grooving the workpiece **105**, the user can disarm the roll groover **100** from the workpiece **105**. The user may actuate the arm/disarm button **120** to disarm the roll groover **100** from the workpiece **105**. The arm/disarm button **120** may be provided on the housing of the roll groover **100**, on a connected display, or an external device **400**.

The method **700** includes controlling, using the electronic processor **200**, the first motor **290** to move the groove roll **145** away from the workpiece **105** (at block **720**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The first motor **290** is controlled to move the groove roll **145** away from the inner roller **140**. In some embodiments, the first motor **290** is used to move the inner roller **140** rather than the groove roll **145** to move the groove roll **145** away from the workpiece **105**.

The method **700** includes determining, using the electronic processor **200**, whether the groove roll **145** is at a home position (at block **730**). The home position may include, for example an extremity of the feedscrew. An optical sensor or other sensor may be used to detect that the groove roll **145** is at a home position. In some embodiments, the electronic processor **200** may also use a current accumulator as described above to determine that the groove roll **145** is at the home position. The electronic processor **200** continues to operate the first motor **290** until the groove roll **145** reaches the home position.

When the groove roll **145** is at the home position, the method **700** includes controlling, using the electronic processor **200**, the first motor **290** to stop (at block **740**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The method **700** includes providing, using the electronic processor **200**, an indication that the roll groover **100** is disarmed (at block **750**). The electronic processor **200** activates an indicator **240** (for example, an LED) to inform the user that the roll groover **100** is disarmed. Once the roll groover **100** is disarmed, the roll groover **100** can be removed from the workpiece **105**.

In some embodiments, the roll groover **100** may include a jog trigger **120** rather than an arm/disarm button **120** to manually operate the groove roll. FIG. **8** is a flowchart of an example method **800** for arming the roll groover **100** using the jog trigger **120**. The method **600** includes detecting, using the electronic processor **200**, actuation of the jog trigger **120** (at block **810**). The user places the roll groover **100** on the workpiece **105** (e.g., a pipe). The roll groover **100** is placed such that the inner roller **140** is received in the inner circumference of the pipe. The inner roller **140** supports the roll groover **100** on the workpiece **105**. The user may then actuate the jog trigger **120** to arm the roll groover **100** onto the workpiece **105**. The jog trigger **120** may be provided on the housing of the roll groover **100**, on a connected display, or the external device **400**.

The method **800** includes controlling, using the electronic processor **200**, the first motor **290** to move the groove roll **145** toward the workpiece **105** (at block **820**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The first motor **290** is controlled to move the groove roll **145** towards the inner roller **140**. In some embodiments, the first motor **290** is used to move the inner roller **140** rather than the groove roll **145** to move the groove roll **145** toward the workpiece **105**.

The method **800** includes determining, using the electronic processor **200**, whether the jog trigger **120** is still actuated (at block **830**). The electronic processor **200** continues to operate the first motor **290** while the jog trigger **120** is actuated. When the jog trigger **120** is continued to be actuated, the method **800** includes detecting, using the one or more sensors **220**, a current drawn by the first motor **290** (at block **840**). The one or more sensors **220** may include, for example, a current sensor that detects an amount of current flowing to the first motor **290**. The current sensor provides a signal indicating the amount of current drawn by the first motor **290** to the electronic processor **200**.

The method **800** includes determining, using the electronic processor **200**, whether the current exceeds an arm threshold of the roll groover **100** (at block **850**). During operation the first motor **290**, the current flow is typically constant where the groove roll **145** does not encounter resistance. When the groove roll **145** contacts the workpiece **105**, the current drawn by the first motor **290** starts increasing. An accumulator may be used to accumulate the current signal and detect a sudden increase in current. The electronic processor **200** determines that the groove roll **145** has contacted the workpiece **105** when the current accumulator reaches the predetermined arm threshold value.

The electronic processor **200** continues operation of the first motor **290** when the current does not exceed the arm threshold. When the current exceeds the arm threshold and/or when the electronic processor **200** determines that the jog trigger **120** is not actuated, the method **800** includes controlling, using the electronic processor **200**, the first motor **290** to stop (at block **860**). The electronic processor **200** controls the first motor **290** to stop using the FET switching module **215**. The method **800** includes providing, using the electronic processor **200**, an indication that the roll groover **100** is armed (at block **870**). The electronic processor **200** activates an indicator **240** (for example, an LED) to inform the user that the roll groover **100** is armed. Once the roll groover **100** is armed, the roll groover **100** can support itself on the workpiece **105**. The user may then remove their hand from the roll groover **100**.

As discussed above, the roll groover **100** may be armed using an arm/disarm button **120** or a jog trigger **120**. Once the roll groover **100** is armed, the roll groover **100** can automatically detect dimensions of the workpiece **105** and the corresponding groove depth. FIG. **9** is a flowchart of an example method **900** for determining groove depth of the workpiece **105**. The method **900** includes detecting, using the electronic processor **200**, actuation of the run button **125** (at block **910**). Once the user receives an indication that the roll groover **100** is armed on the workpiece **105**, the user can actuate the run button **125** to start the grooving process by the roll groover **100**. The run button **125** may be provided on the housing **110** of the roll groover **100**, on a connected display, or the external device **400**.

The method **900** includes determining, using the inertial measurement unit **225**, an initial position of the groove roll **145** (at block **920**). The initial position of the groove roll provides a home position for measuring an outer circumference of the workpiece **105**. The initial position can be determined using, for example, the method **500** for determining a position of the roll groover **100**. Specifically, the inertial measurement unit **225** includes a 9-axis sensor to provide a home position of the groove roll **145**.

The method **900** includes controlling, using the electronic processor **200**, the second motor **295**, to move the groove roll **145** around the workpiece **105** while measuring distance (at block **930**). The electronic processor **200** controls the second motor **295** using the FET switching module **215**. The second motor **295** is controlled to move the groove roll **145** around the track **155** and the workpiece **105**. In some embodiments, the distance is measured using the inertial measurement unit **225** based on the difference between the initial position (e.g., home position) and intermediate positions of the groove roll **145** as further explained below. In some embodiments, the second rotary encoder **320** is used to measure the distance. As explained above, a linear equation may be derived based on the connection between the second motor **295** and the groove roll **145**. The distance traveled can then be calculated using the signals from the second rotary encoder **320** and the linear equation.

The method **900** includes determining, using the electronic processor **200**, whether the groove roll **145** has rotated 360° (at block **940**). For example, the electronic processor **200** may use the inertial measurement unit **225** to detect whether the groove roll **145** is back at the home position after being operated around the circumference of the workpiece **105**. The electronic processor **200** may also use the second rotary encoder **320** to determine the position of the rotor of the second motor **295** to determine whether the groove roll has been rotated 360° around the workpiece **105**. The electronic processor **200** continues rotation of the second motor **295** until the second motor **295** has reached the home position after being rotated around the workpiece **105**.

When the groove roll **145** has rotated 360°, the method **900** includes controlling, using the electronic processor **200**, the second motor **295** to stop and record a measured distance (at block **950**). The electronic processor **200** controls the second motor **295** to stop using the FET switching module **215**. The measured distance is then recorded in, for example, the memory **255**. In one example, the distance is measured using the inertial measurement unit **225**. The electronic processor **200** may determine the initial position and a position that was farthest from the initial position during movement of the groove roll **145** around the workpiece **105**. The electronic processor **200** determines the difference between the initial position and the farthest position as the diameter and can determine the circumference of the workpiece **105** using the diameter. Alternatively, the electronic processor **200** may detect the circumference using the inertial measurement unit **225** and the second rotary encoder **320**. The electronic processor determines the change in angular position of the rotor during the movement of the groove roll **145** around the workpiece **105** from the home position back to the home position. A linear equation previously derived based on the connection between the second motor **295** and the groove roll can be used to determine the circumference of the workpiece **105**. The circumference can then be used to determine the diameter and other dimensions of the workpiece. The diameter and/or the circumference of the workpiece can then be recorded in the memory **255** as the measured distance. Specifically, the dimeter may be recorded as the "C" dimension of the workpiece **105**

The method **900** includes determining, using the electronic processor **200**, a groove depth based on the measured distance (at block **960**). Groove depths vary based on the "C" dimension of the pipe in the pipe fitting industry. Typically, a groove depth is standard for a particular "C" dimension of a pipe. The memory **255** stores a look-up table including a mapping between the "C" dimension and the groove depth. The electronic processor **200** can refer the look-up table stored in the memory **255** to determine whether the measured distance (for example, the "C" dimension) is provided in the look-up table. When the measured distance is provided in the look-up table, the electronic processor **200** uses the corresponding groove depth as the groove depth for operation on the workpiece **105**. When the measured distance is not provided in the look-up table, the electronic processor **200** may use an industry standard formula to determine the groove depth based on the "C" dimension. The determined groove depth is subsequently used to produce the groove in the workpiece **105**. In some embodiments, the groove depth may also be provided as an input on the external device **400**.

FIG. **10** is a flowchart of an example method **1000** for operating the roll groover **100**. The method **1000** includes controlling, using the electronic processor **200**, the second motor **295** to move the groove roll **145** around the workpiece while measuring distance (at block **1010**). The electronic processor **200** controls the second motor **295** using the FET switching module **215**. The second motor **295** is controlled to move the groove roll **145** around the track **155** and the workpiece **105**. In some embodiments, the distance is measured using the inertial measurement unit **225** based on the difference between the initial position (e.g., home position) and a current position of the groove roll **145** as explained below. In some embodiments, the second rotary encoder **320** is used to measure the distance. As explained above, a linear equation may be derived based on the connection between the second motor **295** and the groove roll **145**. The distance traveled can then be calculated using the signals from the second rotary encoder **320** and the linear equation.

The method **1000** includes determining, using the electronic processor **200**, whether the groove roll **145** has traveled a first predetermined distance around the circumference of the workpiece **105** (at block **1020**). As described above, the electronic processor continuously measures the distance traveled by the groove roll **145** around the circumference of the workpiece **105**. The distance is tracked to determine whether the groove roll **145** has reached a point where the groove depth of the groove roll **145** is to be increased. The groove roll **145** starts at an initial groove depth when producing the groove on the workpiece **105**. The groove depth is gradually increased until the determined or desired groove depth is achieved in the workpiece **105**. The electronic processor continues to operate the second motor **295** until the groove roll **145** has traveled the first predetermined distance around the circumference of the workpiece **105**. The first predetermined distance around the circumference may include, for example, half the distance of the circumference, a quarter of the distance of the circumference, a third of the distance of the circumference, or the like.

When the groove roll **145** has traveled the first predetermined distance around the circumference of the workpiece **105**, the method **1000** includes determining, using the electronic processor **200**, whether the groove roll **145** is below a second predetermined distance of the final depth (at block **1030**). As discussed above, the groove depth is gradually increased until the final depth is reached. The depth may be incremented by predetermined distances (for example, the second predetermined distance). However, the final depth may not be an integer multiple of the predetermined depth increments. Accordingly, the electronic processor **200** determines whether the groove roll **145** is below the predetermined depth increment from the final depth.

When the groove roll **145** is not below the second predetermined distance of the final depth, the method **1000** includes controlling, using the electronic processor **200**, the first motor **290** to increase groove depth by predetermined increment (at block **1040**). Once the groove roll **145** has travelled the first predetermined distance around the circumference of the workpiece **105**, the electronic processor **200** stops the second motor to increase the groove depth. In one embodiment, the predetermined increment is the second predetermined distance. The predetermined increment is, for example, a full turn, a half turn, a quarter turn, or the like of the feedscrew used to move the groove roll **145** for increasing or decreasing the depth. The electronic processor **200** controls the first motor **290** to move the groove roll **145** to increase or decrease the groove depth. The method **1000** then continues to block **1010** to operate the second motor **295** and produce the groove in the workpiece **105**. The method **1000** continues to gradually increase the groove depth and produce the groove in the workpiece **105** as discussed in blocks **1010-1040** until the groove depth is below the second predetermined distance of the final depth.

When the groove depth is below the second predetermined distance of the final depth, the method **1000** includes controlling, using the electronic processor **200**, the first motor **290** to increase groove depth by fractional increment (at block **1050**). The fractional increment corresponds to the difference between the final depth (i.e., desired depth) and the current depth. The electronic processor **200** stops the second motor **295** and controls the first motor **290** to turn the feedscrew by the fractional amount for producing the desired groove depth.

The method **1000** includes controlling, using the electronic processor **200**, the second motor **295** to move the groove roll **145** around the workpiece while measuring distance (at block **1060**). Once the final depth is achieved, the electronic processor **200** controls the second motor **295** to complete the grooving operation on the workpiece **105**. The method **1000** includes determine, using the electronic processor **200**, whether the groove roll **145** is at the initial position (at block **1070**). The electronic processor **200** continues operating the second motor **295** until the groove roll **145** has reached the initial position. In some embodiments, determining that the groove roll **145** has reached the initial position includes determining that the grooving process on the workpiece **105** has been completed.

When the groove roll **145** is at the initial position, the method **1000** includes controlling, using the electronic processor **200**, the second motor **295** to stop and indicating completion of operation (at block **1080**). Once the grooving process is complete, the electronic processor **200** stops the motor and provides an indication, for example, using the indicators **240**. The indication informs the user that the grooving operation is complete. The user may then disarm the roll groover **100** from the workpiece **105**.

In some embodiments, the final groove depth and details of the grooving operation may be stored in the memory **255**. A user may connect to the roll groover using the external device running the roll groover application **460**. The user may compare the final groove depth with the manufacturer's specification for the workpiece **105** on the external device **400**.

In some embodiments, the roll groover **100** may include an additional single revolution mode, also referred to as a "1X" mode. The single revolution mode may be activated using a button on the housing **110** of the roll groover **100** or on a user interface of the roll groover **100**. In some embodiments, the single revolution mode may be activated using the roll groover application **460**, for example, by receiving a selection of the single revolution mode. In the single revolution mode, the groove roll **145** complete a single revolution around the workpiece to perform a groove cut on the workpiece **105**. The single revolution mode allows additional applications beyond the current capabilities of the roll groover **100**. For example, the single revolution mode allows a user to achieve the desired depth if the automated operation described in FIG. **10** does not result in the desired depth of cut. In some embodiments, a desired depth may be provided for the single revolution mode or other modes. In this embodiment, the groove roll **145** is operated to achieve the desired depth, for example, when the automated operation described in FIG. **10** does not result in the desired depth. In some embodiments, the 1X mode is controlled wireless by an external device (e.g., a smartphone).

The roll groover **100** described above therefore provides several advantages over roll groovers currently in the market. Specifically, the roll groover **100** is operated using motors thereby removing the need for manually operating the roll groover by a crank mechanism. Additionally, the roll groover **100** automatically determines the groove depth and automatically produces the groove in the workpiece **105**. This provides a more accurate groove in the workpiece by reducing any human error during operation. The groove depth can be verified using the external device **400**. Additionally, the roll groover **100** increases the efficiency and speed of groove rolling operation. Specifically, the user may setup a first operation on a first workpiece **105** by arming a first roll groover **100** on the first workpiece **105** and pressing the run button **125** of the first roll groover **100**. While the first roll groover **100** is operating on the first workpiece, the user may setup a second workpiece **105** by arming a second roll groover **100** on the second workpiece **105** and pressing the run button **125** of the second roll groover **100**.

An automated roll groover **100** such as the one described herein may be subject to certain safety regulations. For example, the roll groover **100** may have to stop operation when an object is detected within a vicinity of the roll groover **100** that may entangle with the operation of the roll groover **100**. The roll groover **100** uses, for example, the LiDAR sensors **330** or other similar proximity detection sensors to detect any objects that may interfere with the operation of the roll groover **100** and stops operation of the roll groover **100** when the objects are detected.

FIG. **11** is a flowchart of an example method **1100** for entanglement awareness of the roll groover **100**. The method **1100** includes detecting, using the electronic processor **200**, that the roll groover **100** is stationary (at block **1110**). The electronic processor **200** receives signals from the inertial measurement unit **225** regarding the movement of the roll groover **100**. A better 3D model may be obtained when the roll groover **100** is stationary compared to when the roll groover **100** is operating. Specifically, an initial 3D model may be obtained after the roll groover **100** is armed on the workpiece **105** and before the operation of the roll groover **100** has started.

The method **1100** includes receiving, at the electronic processor **200**, sensor data from the LiDAR sensors **330** (at block **1120**). The LiDAR sensors **330** may include one or more light emitters and one or more light detectors placed in locations around the roll groover **100**. The light emitter emits light signals that are reflected by surroundings around the roll groover **100** and detected by the light detectors. The LiDAR sensors **330** provide the detection results to the electronic processor **200**.

The method **1100** includes generating, using the electronic processor **200**, a base 3D point cloud based on the sensor data (at block **1130**). The electronic processor **200** uses the sensor data to create a base 3D model of the surrounding of the roll groover **100**. The electronic processor **200** may use commonly known techniques of 3D point cloud construction to generate the base 3D point cloud (e.g., ReCap by Autodesk). The base 3D point cloud can be later used for comparison for detecting whether any object have entered the surrounding of the roll groover **100**.

The method **1100** includes continuing, using the electronic processor **200**, operation of the roll groover **100** (at block **1140**). For example, the electronic processor **200** performs methods **900** and **1000** to produce the groove in the workpiece **105**. The method **1100** includes continuously scanning, using the electronic processor **200**, the LiDAR sensors to generate updated 3D point cloud (at block **1150**). For example, the electronic processor **200** may receive sensor data from the LiDAR sensors at every predetermined interval. The electronic processor **200** continuously updates the 3D point cloud based on the received sensor data.

The method **1100** includes comparing, using the electronic processor **200**, the updated 3D point cloud to the base 3D point cloud (at block **1160**). The electronic processor **200** compares the updated 3D point cloud to the base 3D point cloud to detect any differences within the point clouds. The method **1100** includes determining, using the electronic processor **200**, whether an abnormal object is detected in the updated 3D point cloud (at block **1170**). The electronic processor **200** detects objects by comparing the updated 3D point cloud to the base 3D point cloud. An abnormal object is, for example, an object that was not originally present in the base 3D point cloud. When no abnormal object is detected in the updated 3D point cloud, the method **1100** returns to block **1140** to continue operation of the roll groover **100**.

When an abnormal object is detected in the updated 3D point cloud, the method **1100** includes determining, using the electronic processor **200**, whether the abnormal object is within a predetermined distance of the roll groover **100** (at block **1180**). The predetermined distance is, for example, a pre-calibrated distance within which an object may interfere with the operation of the roll groover **100**. The distance between the object and the roll groover **100** may be determined using the sensor data from the LiDAR sensors **330**. When the abnormal object is not within the predetermined distance of the roll groover **100**, the method **1100** returns to block **1140** to continue operation of the roll groover **100**.

When the abnormal object is within the predetermined distance of the roll groover **100**, the method **1100** includes stopping, using the electronic processor **200**, operation of the roll groover **100** (at block **1190**). The electronic processor **200** stops the first motor **290** and/or the second motor **295** and may provide an indication to the user. For example, the electronic processor **200** may activate an indicator **240** to inform the user than an abnormal object is detected within the vicinity of the roll groover **100**. The electronic processor **200** may resume operation when the object is removed from the vicinity of the roll groover **100**. The method **1100** therefore allows the roll groover **100** to meet safety standards as discussed above.

FIG. **12** is a side perspective view of the roll groover **100** in accordance with an example embodiments. As shown in FIG. **12**, the inner roller **140** is, for example, a female roller including a roller groove **1210**, and the groove roll **145** is, for example, a male roller including a roller projection **1220**. The roller groove **1210** is shaped to correspondingly receive the roller projection **1220**. The force exerted by the roller projection **1220** on the outer circumference of the workpiece **105** and the allowance provided by the roller groove **1210** on the inner circumference of the workpiece **105** together produce the groove on the workpiece **105**.

The groove roll **145** include a replaceable die **1230** or die set. In some embodiments, both the inner roller **140** and the groove roll **145** include replaceable dies that form part of the die set. The die **1230** is replaceable to produce grooves of different sizes or to accommodate workpieces **105** of different sizes. In some embodiments, the roll groover **100** is configured to detect the type and identification information of the die set. For example, a user may input identification information of the die set in the roll groover application **460** or on a user interface of the roll groover **100**. In some embodiments, the roll groover **100** automatically detects the identification information of the die set currently placed on the roll groover **100**. The type of the die set may be determined from the identification information. The roll groover **100** may include a radio frequency identity (RFID) reader to read an RFID tag in the die set. The roll groover **100** or the external device **400** may include a QR code or bar code scanner to scan a QR code or bar code on the die set. Each type of die set may include differing electrical contacts. The roll groover **100** may determine the type of die set based on the electrical contacts of the die set. In some embodiments, each type of die set may contact a different combination of a series of switches provided on the roll groover **100**. The roll groover **100** may determine the type of die set based on detecting the switches contacted by the dies set.

Due to the cutting action, the die **1230** may exhibit wear after repeated use. If the die **1230** is not replaced after exhibiting wear, the quality of the groove generated on the workpiece **105** may deteriorate. In some embodiments, the roll groover application **460** may alert a user to check for wear on the die **1230**. FIG. **13** is a flowchart of an example method **1300** for measuring die wear. The method **1300** includes receiving a first selection for measuring an amount of wear on the die **1230** (at block **1310**). The first selection may be received on a user interface of the roll groover **100**. For example, the user may press a button on the roll groover **100** to initiate measuring die wear. In some embodiments, the first selection may be received on the external device **400** (e.g., a smartphone). Specifically, the external device **400** may track the age of the die **1230** and provide periodic alerts to the user to measure die wear. In response, the user may select an option on the roll groover application **460** to measure die wear.

The method **1300** includes retrieving an initial distance an unworn die moves from a disarmed initial position to contact a fixed point (at block **1320**). The initial distance may be determined during manufacturing and may be stored in the memory **255** or the device memory **420**. When measuring die wear is initiated, the roll groover **100** retrieves the initial distance from the memory **255**. Alternatively, the external device **400** retrieves the initial distance from the device memory **420**. The disarmed initial position may refer to the position of the groove roll **145** when the roll groover **100** is disarmed as discussed above with respect to method **700**. The fixed point may refer to the inner roller **140**. The initial distance is therefore the distance moved by the groove roll **145** when the groove roll **145** is moved from the disarmed initial position to contact the inner roller **140**.

The method **1300** further includes controlling, using the electronic processor **200**, the first motor **290** to move the groove roll **145** from the disarmed initial position to the fixed point in response to receiving the first selection (at block **1330**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The first motor **290** is controlled to move the groove roll **145** towards the inner roller **140**.

The method **1300** also includes measuring, using the electronic processor **200**, a distance moved by the groove roll **145** when the groove roll **145** is moved from the disarmed initial position to contact the fixed point (at block **1340**). In some embodiments, the measured distance is measured using the inertial measurement unit **225**. In other embodiments, the measured distance is measured using the first rotary encoder **310** or revolutions of the motor **290**, **295**. As the die wears, the groove roll **145** travels farther to contact the fixed point compared to an unworn die.

The method **1300** includes determining whether the measured distance is greater than the initial distance (at block **1350**). As the die wears, the groove roll **145** travels farther to contact the fixed point compared to an unworn die. Accordingly, when the measure distance is greater than the initial distance, the electronic processor **200** determines that the die **1230** is worn. In some embodiments, the electronic processor **200** determines that the die **1230** is worn when the measured distance is greater than the initial distance by more than a predetermined amount.

When the measured distance is greater than the initial distance, the method **1300** includes determining that the die **1230** is worn and generating a first indication that the die **1230** is worn (at block **1360**). When the measured distance is not greater than the initial distance, the method **1300** includes determining that the die **1230** is not worn and generating a second indication that the die **1230** is unworn (at block **1370**). The first and second indication may be provided on a user interface of the roll groover **100** (for example, using the indicators **240**) or on a user interface of the external device **400**. When the die **1230** is worn, the external device **400** may prompt the user to replace the die **1230** or to recalibrate the roll groover **100**. Recalibrating the roll groover **100** adjusts the initial position (e.g., the home position) based on the worn amount such that the roll groover **100** may accurately produce the groove on the workpiece **105**.

In some embodiments, the groove roll **145** may also be used to determine dimensions of the workpiece **105**. The dimensions of the workpiece **105** include, for example, a thickness of the workpiece **105** (e.g., pipe) or a depth of a groove in the workpiece **105**. FIG. **14** is a flowchart of an example method **1400** for measuring workpiece dimension. The method **1400** includes receiving a second selection for measuring a workpiece dimension (at block **1410**). The second selection may be received on a user interface of the roll groover **100**. For example, the user may press a button on the roll groover **100** to initiate measuring workpiece dimension. In some embodiments, the second selection may be received on the external device **400**. Specifically, the user may select an option on the roll groover application **460** to measure a workpiece dimension. The workpiece dimension is, for example, a thickness of the workpiece **105** or a depth of a groove in the workpiece **105**.

The method **1400** includes retrieving an initial distance the groove roll moves from a disarmed initial position to contact the inner roller **140** (at block **1420**). The initial distance may be determined during manufacturing and may be stored in the memory **255** or the device memory **420**. When measuring workpiece dimension is initiated by the second selection, the roll groover **100** retrieves the initial distance from the memory **255**. Alternatively, the external device **400** retrieves the initial distance from the device memory **420**. The disarmed initial position may refer to the position of the groove roll **145** when the roll groover **100** is disarmed as discussed above with respect to method **700**. The initial distance is therefore the distance moved by the groove roll **145** when the groove roll **145** is moved from the disarmed initial position to contact the inner roller **140**.

The method **1400** further includes controlling, using the electronic processor **200**, the first motor **290** to move the groove roll **145** from the disarmed initial position to contact the workpiece **105** in response to receiving the second selection (at block **1430**). The electronic processor **200** controls the first motor **290** using the FET switching module **215**. The first motor **290** is controlled to move the groove roll **145** towards the inner roller **140**.

The method **1400** also includes measuring, using the electronic processor **200**, a distance moved by the groove roll **145** when the groove roll **145** is moved from the disarmed initial position to contact the workpiece **105** (at block **1440**). In some embodiments, the measured distance is measured using the inertial measurement unit **225**. In other embodiments, the measured distance is measured using the first rotary encoder **310**.

The method **1400** includes determining the workpiece dimension based on a difference between the measured distance and the initial distance (at block **1450**). The thickness of the workpiece **105** can be determined by subtracting the measured distance from the initial distance. The groove depth can be determined by subtracting a measured thickness of the workpiece **105** from a known thickness of the workpiece. The known thickness of the workpiece can be determined based on identifying the type of workpiece **105** and retrieving prestored values for each type of workpiece **105**. The groove depth measured by method **1400** is the depth of a groove currently present in a workpiece **105**. The groove depth measured by method **1400** is therefore distinct from the groove depth measured by method **900**. The groove depth measured by method **1400** pertains to a groove depth that is to be ultimately achieved by the operation of the roll groover **100** (i.e., a prospective groove depth) based on a "C" dimension of the workpiece **105**.

In some embodiments, the method **1400** may also be used to determine whether a workpiece **105** has already been grooved. For example, the electronic processor **200** compares the workpiece dimension to an expected thickness of the workpiece **105**. The electronic processor **200** determines that the workpiece **105** is already grooved when the workpiece dimension is smaller than the expected thickness of the workpiece **105**. The electronic processor **200** may also determine whether the workpiece **105** is grooved to an expected specification by determining the difference between workpiece dimension and the expected thickness and comparing the difference to a predetermined threshold. The predetermined threshold corresponds to the expected groove depth for the particular type of workpiece **105**. When the electronic processor **200** determines that the groove depth does not match the expected specification, the electronic processor **200** continues operation of the roll groover **100** to roll a groove on the workpiece **105**. When the electronic processor **200** determines that the groove depth matches the expected specification, the electronic processor **200** stops operation of the roll groover **100**.

In some embodiments, the roll groover **100** may also perform walk-off detection to detect whether the roll groover **100** is moving away from the workpiece **105** in the Z-axis (i.e., in the axial direction of the workpiece **105**). The walk-off detection may be performed using, for example, a limit switch **1240** (see FIG. **12**) provided on the housing **110** of the roll groover **100**. The limit switch **1240** may be a biased physical switch provided at an interface of the workpiece **105** and the housing **110**. The limit switch **1240** is normally biased into an open position (e.g., OFF position). When the workpiece **105** is properly attached to the housing **110** for operation, the workpiece **105** depresses/actuates the limit switch **1240** to a closed position (e.g., ON position). When in the closed position, the physical limit switch **1240** may close (i.e., turn ON) an electronic limit switch. When closed, the electronic limit switch provides a signal to the electronic processor **200** indicating that the workpiece **105** is properly attached to the housing **110**. When the workpiece **105** begins to walk-off, the workpiece releases the limit switch **1240**, which moves into an open position due to a biasing force and which in turn opens the electronic limit switch. In the absence of a signal from the electronic limit switch, the electronic processor **200** detects walk-off of the workpiece **105** from the roll groover **100**. In some embodiments, the electronic limit switch may be closed or turned ON when the physical limit switch **1240** is not depressed/actuated. In these embodiments, the electronic processor **200** detects walk-off when a signal is detected from the electronic limit switch as the electronic limit switch is turned ON when the physical limit switch **1240** is released. The physical limit switch **1240** may be configured such that the electronic limit switch is turned ON/OFF prior to complete disengagement of the workpiece **105** from the housing **110**.

In some embodiments, walk-off detection is performed using, for example, the inertial measurement unit **225** based on the displacement of the roll groover **100** during operation. Specifically, the electronic processor **200** monitors the movement of the roll groover **100** in the Z-axis using the inertial measurement unit **225**. When a movement in the Z-axis exceeds a predetermined walk-off threshold, the electronic processor **200** detects a walk-off of the workpiece **105** from the roll groover **100**.

In some embodiments, the roll groover **100** may also be used to detect an oblong pipe (e.g., not the correct shape to fit a coupling). For example, the inertial measurement unit **225** detects the movement of the groove roll **145** around the workpiece **105**. The roll groover **100** may store a predetermined profile of the inertial measurement unit **225** measurements for a circular pipe. The electronic processor **200** detects an oblong pipe when the measurements for the current movement of the groove roll **145** deviate from the predetermined profile. In some embodiments, the roll groover **100** may also be used to detect a flared pipe, that is, when the outer edge of the workpiece **105** is flared. The roll groover **100** includes a sensor to detect an angle of the roll groover **100** compared to the workpiece **105**. The electronic processor **200** detects a flared pipe when the detected angle deviates from a predetermined angle. The sensor for detecting a flared pipe includes, for example, the inertial measurement unit **225**, the LIDAR sensors **330**, an ultrasonic sensor, and the like. The inertial measurement unit **225** may be used to detect the current profile (e.g., an inner diameter and shape of a pipe) of the workpiece **105** and detect a flared pipe when the current profile deviates from an expected profile. The LIDAR sensors **330** or the ultrasonic sensor may be used to measure the distance of various points of the workpiece **105** to detect a flared pipe.

Thus, embodiments described herein provide, among other things, a roll groover for producing connection grooves on pipes.

What is claimed is:

1. A roll groover comprising:
- a housing;
- a user input on the housing;
- an inner roller provided on the housing and configured to be received in an inner circumference of a workpiece;
- a groove roll provided on the housing and configured to produce a groove on the workpiece;
- one or more motors provided within the housing and configured to drive the groove roll;
- an electronic processor electrically connected to the one or more motors, the electronic processor configured to:
- receive an arm input from the user input;

drive the groove roll toward the workpiece in a first radial direction using the one or more motors;
receive one or more sensed values in response to driving the groove roll;
determine whether the groove roll has contacted the workpiece based on the one or more sensed values exceeding a predetermined threshold;
cease driving the groove roll in the first radial direction in response to determining that the one or more sensed values have exceeded the predetermined threshold; and
generate an indication that the roll groover is armed.

2. The roll groover of claim **1**, wherein the one or more motors includes:
- a first motor configured to drive the groove roll in the radial direction; and
- a second motor configured to drive the groove roll in a circumferential direction.

3. The roll groover of claim **1**, wherein the one or more sensed values include a current output of the one or more motors.

4. The roll groover of claim **1**, wherein the electronic processor is further configured to:
- receive a disarm input from the user input;
- drive the groove roller away from the workpiece in a second radial direction using the one or more motors;
- determine whether the groove roll is in a home position; and
- cease driving the groove roll in the second radial direction in response to determining that the groove roll is in the home position.

5. The roll groover of claim **4**, wherein the home position is an extremity of a feedscrew used to drive the groove roll in the first radial direction and the second radial direction.

6. The roll groover of claim 1, wherein the electronic processor is further configured to:

operate the one or more motors to move the groove roll in a circumferential direction to produce a groove on the workpiece;

control the one or more motors to move the groove roll around the workpiece while measuring a distance; and

increase, using the one or more motors, a groove depth in predetermined increments for each rotation of the groove roll by a first predetermined distance.

7. The roll groover of claim 6, wherein the electronic processor is further configured to:

receive a selection of a single revolution mode; and

control the one or more motors to complete a single revolution of the groove roll around the workpiece.

8. The roll groover of claim 6, wherein the one or more motors includes:

a first motor configured to drive the groove roll in the first radial direction; and

a second motor configured to drive the groove roll in the circumferential direction.

9. A roll groover comprising:

a housing;

an inner roller provided on the housing and configured to be received in an inner circumference of a workpiece;

a groove roll provided on the housing and configured to produce a groove on the workpiece;

one or more motors provided within the housing and configured to drive the groove roll;

a battery pack configured to power the one or more motors; and

an electronic processor electrically connected to the one or more motors, the electronic processor configured to:

operate the one or more motors to perform a first operation of moving the groove roll in a first radial direction to engage the workpiece, and

operate the one or more motors to perform a second operation of moving the groove roll in a circumferential direction, wherein the second operation is performed to produce a groove on the workpiece, and

operate the one or more motors to perform a third operation of moving the groove roll in a radial direction to disengage the workpiece.

10. The roll groover of claim 9, wherein the electronic processor is further configured to:

control the one or more motors to move the groove roll around the workpiece while measuring a distance; and

increase, using the one or more motors, groove depth in predetermined increments for each rotation of the groove roll by a first predetermined distance.

11. The roll groover of claim 9, wherein the electronic processor is further configured to, while performing the first operation:

receive an arm input from a user input;

drive the groove roll toward the workpiece in a first radial direction using the one or more motors;

receive one or more sensed values in response to driving the groove roll;

determine whether the groove roll has contacted the workpiece based on the one or more sensed values exceeding a predetermined threshold;

cease driving the groove roll in the first radial direction in response to determining that the one or more sensed values have exceeded the predetermined threshold; and

generate an indication that the roll groover is armed.

12. The roll groover of claim 9, further comprising:

an arm/disarm switch configured to control the first operation and the third operation;

a run switch configured to control the second operation; and

a direction switch configured to select a direction of movement of the groove roll.

13. The roll groover of claim 9, wherein the electronic processor is further configured to:

determine whether the roll groover is moving in an axial direction away from the workpiece; and

detect a walk-off condition in response to determining that the roll groover is moving away from the workpiece.

14. The roll groover of claim 13, wherein the electronic processor is further configured to:

detecting one or more objects in a proximity to the roll groover;

determine whether the proximity of the object is sufficient to cause interference with the roll groover while operating in the second operation; and

stopping the second operation in response to detecting that the proximity of the object is sufficient to cause interference.

15. The roll groover of claim 9, wherein the electronic processor is further configured to:

control the one or more motors to move the groove roll around the workpiece while measuring distance;

determine whether the groove roll has traveled a first predetermined distance around a circumference of the workpiece;

determine whether the groove roll is below a second predetermined distance of a final depth when the groove roll has traveled the first predetermined distance;

in response to the groove roll not being below the second predetermined distance of the final depth, control the one or more motors to increase groove depth by a predetermined increment; and

in response to the groove roll being below the second predetermined distance of the final depth:

control the one or more motors to increase groove depth by a fractional increment,

control the one or more motors to move the groove roll around the workpiece,

determine whether the groove roll is at an initial position, and

control the one or more motors to stop and indicate completion of operation when the groove roll is at the initial position.

16. The roll groover of claim 9, wherein the groove roll is a replaceable die.

17. A method of operating a roll groover including an inner roller configured to be received in an inner circumference of a workpiece and a groove roll configured to produce a groove on the workpiece, the method comprising:

operating, using an electronic processor; one or more motors to perform a first operation of moving the groove roll in a first radial direction to engage the workpiece;

operating, using the electronic processor, one or more motors to perform a second operation of moving the groove roll in the radial direction, wherein the second operation is performed to adjust a groove depth on the workpiece; and

operating, using the electronic processor, the one or more motors to perform a third operation of moving the groove roll in a circumferential direction, wherein the third operation is performed to produce the groove on the workpiece;

providing, using a battery pack, power to the one or more motors.

18. The method of claim **17**, further comprising:

controlling the one or more motors to move the groove roll around the workpiece while measuring a distance; and

increasing, using the one or more motors, groove depth in predetermined increments for each rotation of the groove roll by a first predetermined distance.

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