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# BOLTER


## Abstract

A drilling and bolting rig includes a carousel rotatable about a carousel axis and including a plurality of stations configured to support a plurality of consumables, one or more actuators, and a position sensor coupled to the carousel. The one or more actuators are configured to rotate the carousel about the carousel axis. The drilling and bolting rig further includes an electronic processor coupled to the one or more actuators and the position sensor. The electronic processor is configured to detect, using the position sensor, a rotational position of the carousel, and rotate, using the one or more actuators, the carousel based on the rotational position of the carousel.



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## Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of co-pending U.S. patent application Ser. No. 18/342,218, filed Jun. 27, 2023, which is a divisional of and claims priority to U.S. Pat. No. 11,725,514, filed Oct. 1, 2021, which claims priority to U.S. Provisional Patent Application No. 63/086,392, filed Oct. 1, 2020. The entire contents of these applications are incorporated herein by reference.

FIELD

[0002] The present disclosure relates to a drill rig, and more particularly to an underground drill rig.

[0003] In underground mining and construction, drill rigs perform drilling and bolting operations. One common use for a drill rig is to reinforce a roof or wall section with a reinforcement member (e.g., a rebar bolt). In order to perform drilling operations, the drill rig requires a supply of consumables.

SUMMARY

[0004] The disclosure provides, in one aspect, a drilling and bolting rig for performing drilling and bolting operations. The drilling and bolting rig includes a magazine for storing a consumable, a feed supporting a drill head for movement relative to a work surface, and a loader configured to retrieve the consumable from the magazine and load the consumable into the drill head. The loader includes an arm operable to engage the consumable. The arm is supported for both rotational and translational movement.

[0005] In some aspects, the consumable is at least one of a plurality of consumables, and the plurality of consumables includes at least two of a drill bit, a resin cartridge, a resin injector, a first bolt, a second bolt, an adaptor, and an extension rod.

[0006] In some aspects, the magazine includes a carousel rotatable about a first axis to selectively place the consumable into a loading position in which the consumable can be retrieved by the loader, and the carousel is rotatable about the first axis in response to a first actuator.

[0007] In some aspects, the loader includes a loading arm rotatable about a second axis that is offset relative the first axis, and the loading arm is configured to remove the consumable from the loading position on the carousel and move the consumable to position an end of the consumable in the drill head.

[0008] In some aspects, the feed is extendable along a drill axis oriented parallel relative to at least one of the first axis and the second axis.

[0009] In some aspects, the drive unit is operable to apply the desired consumable to the work surface, and the loading arm is rotatable about the second axis to retrieve the consumable from the drill head.

[0010] In some aspects, the magazine includes a carousel rotatable about an axis, and a distance between the drill head and an axis of rotation of the loading arm is equal to a distance between the axis of rotation of the loading arm and the axis about which the carousel rotates.

[0011] In some aspects, rotation of the carousel is automated by a controller to define at least a portion of a drill cycle in which the consumable retrieved from the loading position on the carousel is replaced with another consumable by rotating the other consumable into the loading position.

[0012] In some aspects, rotation of the loading arm is automated by the controller and selectively replaces the one consumable with the other consumable.
[0013] In some aspects, the one consumable includes a drill bit and the other consumable includes a resin cartridge.
[0014] In some aspects, another consumable includes a bolt, and the loading arm is automated by the controller to transfer the bolt to the drive unit, the drive unit inserting the bolt into resin in the work surface in a bolt cycle.
[0015] In some aspects, the drill cycle, the resin cycle, and the bolt cycle are automated by the controller such that the manual interaction of a human operator is unnecessary for operation of the underground mining and construction rig.
[0016] In some aspects, the carousel supports each of the plurality of consumables at a predetermined position, and the carousel includes a feature aligned with one of the plurality of consumables, the feature engaging a bypass actuator when the one of the plurality of consumables is aligned with the loading arm to modify a path of movement of the loading arm
[0017] In some aspects, the feature is a protrusion positioned on a portion of the carousel and the bypass actuator is coupled to a valve, actuation of the valve causing fluid flow to bypass a hydraulic circuit associated with an extension of the loading arm.
[0018] In some aspects, the loader includes a support member, a loading arm supported for rotation relative to the support member, and a gripper supported on the loading arm, the support member including a first port, the loading arm including a second port in fluid communication with the first port while the loading arm rotates to provide pressurized fluid to an actuator, the actuator operating at least one of the loading arm and the gripper.
[0019] In some aspects, the loader includes a support member, a loading arm supported for rotation relative to the support member, and a gripper supported on the loading arm, the support member including a mast, a sleeve slidably supported on the mast, a key extending through the sleeve and engaging the mast to guide sliding movement of the loader, the support member further including a retainer for maintaining the key in engagement with the mast, the retainer including a first portion extending around a first peripheral portion of the sleeve and a second portion extending around a second peripheral portion of the sleeve.
[0020] The disclosure provides, in another aspect, a drilling and bolting rig for performing automated drilling and bolting operations. The drilling and bolting rig includes a magazine supporting a consumable, a feed moveably supporting a driver relative to a work surface, a loader including an arm configured to transfer the consumable from the magazine to the driver, and a washer loader configured to transfer a washer from a washer store to be positioned adjacent the consumable. The washer includes an aperture configured to receive the consumable therethrough.
[0021] In some aspects, the washer store is arranged in a refillable stack.
[0022] In some aspects, the washer loader includes a carrier arm having a portion configured to magnetically engage a single washer from the washer store.
[0023] In some aspects, the drilling and bolting rig for performing automated drilling and bolting operations further includes a support configured to maintain the washer in a predetermined position relative to the consumable as the consumable and washer are transferred to the driver.
[0024] In some aspects, the washer loader includes a carrier arm, further including a protrusion for guiding the washer as the consumable and washer are transferred to the driver, the protrusion extending from the carrier arm.
[0025] In some aspects, the washer loader may optionally bypass placement of at least one washer of the washer store when the consumable is transported to driver by the loader.
[0026] In some aspects, the consumable is one of a plurality of consumables supported by the magazine, the plurality of consumables including at least two of a drill bit, a resin cartridge, a resin injector, a first bolt, a second bolt, an adaptor, and an extension rod.
[0027] In some aspects, the drilling and bolting rig for performing automated drilling and bolting

operations further includes a controller configured to automate operation of the magazine, the loader, the feed, and the washer loader such that the bit, bolt, and the washer are transported to the work surface without manual interaction of a human operator.

[0028] In some aspects, the washer loader includes a carrier arm configured to engage the washer and a carrier actuator supporting the carrier arm, the washer loader further including a guide groove coupled to one of the carrier arm and the carrier actuator, and a guide coupled to the other of the carrier arm and the carrier actuator, the guide received within the guide groove, wherein operation of the actuator causes the guide to move along the guide groove to move the carrier arm along a predetermined path.

[0029] In some aspects, at least a portion of the guide groove is curvilinear, movement of the guide in the guide groove causing rotation of the carrier arm in response to operation of the carrier actuator.

[0030] In some aspects, the guide groove includes a first groove portion and a second groove portion releasably secured relative to the first groove portion, wherein a position of the first groove guide portion relative to the second groove guide portion may be adjusted, thereby adjusting at least one of a starting position and an ending position of the carrier arm.

[0031] In some aspects, the washer loader includes a carrier arm configured to engage the washer, the carrier arm being rotatable about an axis by a first carrier actuator and moveable in a radial direction relative to the axis by a second carrier actuator.

[0032] In some aspects, the washer loader includes a carrier arm configured to engage the washer, the carrier arm being extendable along a first axis by a first carrier actuator and moveable along a second axis offset relative the first axis by a second carrier actuator, and the carrier arm is moveable along at least one of the first axis and the second axis to move the washer.

[0033] The disclosure provides, in another aspect, a drilling and bolting rig for performing automated drilling and bolting operations. The drilling and bolting rig includes a magazine including a mast, a carousel rotatable relative the mast about a carousel axis and including a plurality of stations, at least some of the stations configured to support a consumable, the plurality of stations being positioned around the mast, and an actuator positioned within the mast, the actuator configured to rotate the carousel about the carousel axis. The drilling and bolting rig includes a magazine further including a loader configured to retrieve at least one of the consumables from the magazine and transfer the consumable into a drive unit.

[0034] In some aspects, the drilling and bolting rig further includes a feed supporting the drive unit for movement relative to the work surface along a longitudinal direction, and the longitudinal direction is parallel to the carousel axis.

[0035] In some aspects, the drilling and bolting rig further includes a controller configured to operate the loader to retrieve the consumable from the magazine and transfer the consumable to the drive unit, and configured to operate the drive unit and feed to insert the consumable into a work surface without requiring manual interaction of a human operator.

[0036] The disclosure provides, in another aspect, a magazine for storing consumables for a drilling and bolting rig. The magazine includes a mast, a carousel supported for rotation relative the mast about an axis, and a clip supported on the carousel. The clip is configured to retain a consumable. The clip is removably coupled to the carousel.

[0037] In some aspects, the magazine further includes an actuator for rotating the carousel about the axis. The actuator is positioned within the mast.

[0038] In some aspects, the clip includes a biasing finger providing a biasing force configured to retain the consumable within a slot, the biasing finger being deformable in response to a force exerted on the finger to permit removal of the consumable from the slot.

[0039] In some aspects, the clip is one of a plurality of clips, and the carousel includes at least one rack configured to support the plurality of clips, the clip being removably coupled to the rack by a fastener.

[0040] In some aspects, the plurality of clips are arranged circumferentially about the axis.
[0041] In some aspects, the clip is configured to engage a consumable of a first type, the clip being replaceable with a clip configured to engage a consumable of a second type.
[0042] In some aspects, a portion of the clip configured to engage the consumable includes a wear member along which the consumable may slide as the consumable is inserted into and removed from the clip.
[0043] In some aspects, the carousel is rotatable to position the clip in a loading position in which a loader is configured to engage the consumable. The loader is configured to remove the consumable from the clip and transport the consumable to a feed.
[0044] The disclosure provides, in another aspect, a drilling and bolting rig that includes a drill head for driving a consumable into a work surface, a feed supporting the drill head for movement relative to a work surface, a hydraulic circuit including, at least one auxiliary flow control valve for selectively controlling flow of pressurized fluid to one of a first hydraulic component and a second hydraulic component, and a main flow control valve for controlling flow of pressurized fluid to the at least one auxiliary flow control valve. The at least one auxiliary flow control valve and the main flow control valve are movable between a first configuration and a second configuration. Pressurized fluid is provided to operate the first hydraulic component while the at least one auxiliary flow control valve and the main flow control valve are in the first configuration. Pressurized fluid is provided to operate the second hydraulic component while the at least one auxiliary flow control valve and the main flow control valve are in the second configuration.
[0045] In some aspects, the first hydraulic component is operable to perform one of the following functions: index tilt the feed in a left/right direction; index tilt the feed in a fore/aft direction; rotate a consumable store; raise/lower a loading arm for loading the consumable; rotate the loading arm; open/close jaws for gripping the consumable; and operate a washer loading arm for loading a washer.
[0046] In some aspects, the second hydraulic component is operable to perform another one of the following functions: index tilt the feed in a left/right direction; index tilt the feed in a fore/aft direction; rotate a consumable store; raise/lower a loading arm for loading the consumable; rotate the loading arm; open/close jaws for gripping the consumable; and operate a washer loading arm for loading a washer.
[0047] In some aspects, the first hydraulic component is operable to actuate a portion of the feed, and the second hydraulic component is operable to actuate a portion of a magazine.
[0048] In some aspects, the first hydraulic component is operable to actuate a portion of the feed, and the second hydraulic component is operable to actuate a portion of a loading arm for transferring the consumable from a magazine to the drill head.
[0049] In some aspects, the drilling and bolting rig further includes a loader configured to retrieve the consumable from a magazine and load the consumable into a drill head. The loader includes an arm operable to engage the consumable. The arm is supported for both rotational and translational movement.
[0050] In some aspects, the hydraulic circuit further includes a function select line selectively providing pressurized fluid to move the at least one auxiliary flow control valve between the first configuration and the second configuration.
[0051] In some aspects, function select line may be toggled between a first pressure condition in which the at least one auxiliary flow control valve is in a first position and a second pressure condition in which the at least one auxiliary flow control valve is in a second position.
[0052] In some aspects, the at least one auxiliary flow control valve includes a first auxiliary flow control valve associated with the first hydraulic component and a second auxiliary flow control valve associated with the second hydraulic component. Each of the first auxiliary flow control valve and the second auxiliary flow control valve are moveable between a first position and a second position.

[0053] In some aspects, the first auxiliary flow control valve and the second auxiliary flow control valve are neutrally biased toward the first position in which pressurized fluid is directed to operate the first hydraulic component, and movement of the first auxiliary flow control valve and the second auxiliary flow control valve to the second position causes pressurized fluid to be directed to operate the second hydraulic component.
[0054] In some aspects, the first hydraulic component is part of a first sub-circuit and the second hydraulic component is part of a second sub-circuit that is arranged in parallel with the first sub-circuit.
[0055] In some aspects, the main flow control valve is a three-position, solenoid-actuated, electronically-controlled valve, and the at least one auxiliary flow control valve is a two-position, hydraulic valve.
[0056] In some aspects, the at least one auxiliary flow control valve is biased toward a neutral position in which pressurized fluid is directed to operate the first hydraulic component.
[0057] The disclosure provides, in one aspect, a drilling and bolting rig comprising: a carousel rotatable about a carousel axis and including a plurality of stations configured to support a plurality of consumables; one or more actuators configured to rotate the carousel about the carousel axis; a position sensor coupled to the carousel; and an electronic processor coupled to the one or more actuators and the position sensor. The electronic processor is configured to detect, using the position sensor, a rotational position of the carousel; and rotate, using the one or more actuators, the carousel based on the rotational position of the carousel.
[0058] In some aspects, the position sensor is a magnetic rotary encoder.
[0059] In some aspects, the position sensor includes a Hall-sensor.
[0060] In some aspects, the position sensor is an intrinsically safe position sensor and includes an encoder housing, and the encoder housing is fixed to the carousel such that the Hall-sensor extends into the carousel and is in close proximity to a magnet attached to the carousel.
[0061] The disclosure provides, in another aspect, a control panel for a drill rig of an automatic bolter comprising: a keypad including an overlay; a plurality of buttons provided on the keypad and configured to control various functions of the drill rig; a plurality of force sensing resistor material corresponding to the plurality of buttons provided below the overlay, wherein a drop in resistance of a force sensing resistor material of the plurality of force sensing resistor material corresponds to a force applied to the corresponding button of the plurality of buttons; and a display and a speaker provided on the keypad. The plurality of buttons are divided between a plurality of control button banks, each control button bank of the plurality of control button banks corresponding to a particular component of the drill rig.
[0062] In some aspects, the overlay has a thickness between 0.15 millimeters (mm) and 3 mm.
[0063] In some aspects, the control panel further includes a first light emitting diode (LED) and a second LED corresponding to a first operation and a second operation of the drill rig. The first LED provides a status indication of the first operation, and the second LED provides a status indication of the second operation. The first LED and the second LED are multicolor LEDs.
[0064] In some aspects, the control panel further includes a first landmark provided between a first control button bank and a second control button bank of the plurality of control button banks.
[0065] In some aspects, the control panel further includes a second set of landmarks provided around a first button and a second button of the first control button bank.
[0066] In some aspects, the control panel further includes a third landmark around a third button of the first control button bank and a fourth button provided below the third button without a landmark.
[0067] In some aspects, the first landmark, the second set of landmarks and the third landmark are raised landmarks.
[0068] In some aspects, the second set of landmarks and the third landmark are engraved landmarks.

[0069] In some aspects, the first button is provided above a second button, wherein the second set of landmarks are directional landmarks indicating upwards and downwards directions around the first button and the second button respectively, wherein the first button and the second button control an upward and downward movement respectively of a component of the drill rig.
[0070] In some aspects, the third landmark is a directional landmark indicating an upwards direction around the third button, wherein the third button and the fourth button control a clockwise and counterclockwise rotation respectively of a component of the drill rig.
[0071] In some aspects, the control panel further includes a bounding box provided around the first control button bank.
[0072] In some aspects, the control panel further includes a connector that allows a connection of a second control panel configured to control the automatic bolter from a distance.
[0073] The disclosure provides, in another aspect, a method for fully automated operation of a drill rig for an automatic bolter, the method comprising: receiving, with a controller of the drill rig, a full automation mode request; automatically performing, using the drill rig, a drilling operation on a working surface in response to receiving the full automation mode request; automatically performing, using the drill rig, a resin injection operation on the working surface subsequent to the drill operation; and automatically performing, using the drill rig, a bolting operation on the working surface subsequent to the resin injection operation
[0074] In some aspects, the method further includes determining, using the controller, whether an error has occurred during one of the automatic drilling operation, the automatic resin injection operation, and the automatic bolting operation; directing a user to manually perform an operation when the error has occurred; receiving, via a control panel, user input corresponding to the operation; and performing, using the controller, the operation based on user input.
[0075] In some aspects, the method further includes determining, using the controller, whether the error is resolved; generating, using the controller, an alert indicating that the drill rig is ready for automated operation; receiving, via the control panel, an input to resume automated operation; and resuming, using the controller, one of the drilling operation, the resin injection operation, and the bolting operation.
[0076] In some aspects, performing one of the automatic drilling operation, the automatic resin injection operation, and the automatic bolting operation includes rotating the carousel to one of a drill loading position, a resin cartridge loading position, a bolt loading position, and an adapter loading position.
[0077] In some aspects, rotating the carousel to one of the drill loading position, the resin cartridge loading position, the bolt loading position, and the adapter loading position further includes controlling, using the controller, a first actuator based on rotation position signals received from an intrinsically safe rotary encoder of the carousel.
[0078] The disclosure provides, in another aspect, a drill rig for an automatic bolter comprising: a carousel rotatable about an axis and configured to store one or more consumables; a drill head configured to apply the one or more consumables to a working surface; and a loading assembly. The loading assembly includes a loading arm configured to move laterally between the carousel and the drill head, and clamps at one end of the loading arm configured to secure the one or more consumables. The drill rig further includes a controller coupled to the carousel, the drill head, and the loading assembly. The controller is configured to receive a full automation mode request; automatically perform a drilling operation on the working in response to receiving the full automation mode request; automatically perform a resin injection operation on the working surface subsequent to the drill operation; and automatically perform a bolting operation on the working surface subsequent to the resin injection operation.
[0079] In some aspects, to automatically perform the bolting operation, the controller is further configured to: rotate, using a first actuator, the carousel to a bolt loading position; secure a bolt from the carousel to the loading arm; load, using the loading arm, the bolt to the drill head; align,

using the drill head, the bolt with a hole in the working surface; rotate, using the first actuator, the carousel to an adapter loading position; secure the adapter from the carousel to the loading arm; load, using the loading arm, the adapter to the drill head; drive, using the drill head and the adapter, the bolt into the working surface; secure the adapter from the drill head to the loading arm; and unload, using the loading arm, the adapter to the carousel.

[0080] In some aspects, the controller is further configured to determine whether an error has occurred during one of the automatic drilling operation, the automatic resin injection operation, and the automatic bolting operation; direct a user to manually perform an operation when the error has occurred; receive, via a control panel, user input corresponding to the operation; and perform the operation based on user input.

[0081] In some aspects, the controller is further configured to determine whether the error is resolved; generate an alert indicating that the drill rig is ready for automated operation; receive, via the control panel, an input to resume automated operation; and resume one of the drilling operation, the resin injection operation, and the bolting operation.

[0082] In some aspects, the drill rig further includes a first actuator configured to rotate the carousel about the axis; and an intrinsically safe rotary encoder mounted to the carousel and configured to provide rotation position signals corresponding to a rotary position of the carousel. The controller is coupled to the first actuator and the intrinsically safe rotary encoder and the controller is further configured to control the first actuator to rotate the carousel to one of the drill loading position, resin cartridge loading position, the bolt loading position, and the adapter loading position based on the rotation position signals received from the intrinsically safe rotary encoder.

[0083] Other aspects of the disclosure will become apparent by consideration of the detailed description and accompanying drawings.

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## Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0084] FIG. **1** is a perspective view of a drill rig in accordance with an embodiment of the disclosure.

[0085] FIG. **2** is another perspective view of the drill rig of FIG. **1**.

[0086] FIG. **3** is a top view of the drill rill of FIG. **1**.

[0087] FIG. **4** is a perspective view of the drill rig of FIG. **1**, illustrating a carousel.

[0088] FIG. **5** is a partial perspective view of the carousel of FIG. **4**.

[0089] FIG. **6** is a partial perspective view of the drill rig of FIG. **1**, illustrating an actuator carried on the carousel.

[0090] FIG. **7** is a partial perspective view of the carousel of FIG. **4**, illustrating a plurality of clips on the carousel.

[0091] FIG. **8** is a perspective view of one of the plurality of clips of FIG. **7**.

[0092] FIG. **9**A is a perspective view of the drill rig of FIG. **1**, illustrating a washer loader.

[0093] FIG. **9**B is another perspective view of the drill rig of FIG. **1**, illustrating a cam in engagement with a valve actuator.

[0094] FIG. **10** is a perspective view of the washer loader of FIG. **9**, illustrating a portion of an actuator cylinder as transparent.

[0095] FIG. **11**A is a perspective view of a carrier arm of the washer loader of FIG. **9**.

[0096] FIG. **11**B is a partial perspective view of the drill rig of FIG. **1**.

[0097] FIG. **12**A is a perspective view of an alternate washer loader useable with the drill rig of FIG. **1**, illustrating the alternate washer loader in a loading position.

[0098] FIG. **12**B is a perspective view of the alternate washer loader of FIG. **12**A, illustrating the alternate washer loader in a lifted position.

[0099] FIG. **12**C is a perspective view of the alternate washer loader of FIG. **12**A, illustrating the alternate washer loader in a lifted and retracted position.
[0100] FIG. **12**D is a perspective view of the alternate washer loader of FIG. **12**A, illustrating the alternate washer loader in bit receiving position.
[0101] FIG. **13**A is a partial perspective view of the drill rig of FIG. **1**, illustrating a loading arm assembly.
[0102] FIG. **13**B is a cross-sectional top view of a portion of the loading arm assembly of FIG. **13**A, taken along the section line **13**B-**13**B of FIG. **13**A.
[0103] FIG. **14**A is a perspective view of a loading arm of the loading arm assembly of FIG. **13**.
[0104] FIG. **14**B is a partially exploded perspective view of an oil coupling and support of the loading arm of FIG. **14**A.
[0105] FIG. **14**C is a cross-sectional side view of the support of FIG. **14**B.
[0106] FIG. **15** is a hydraulic circuit for the drill rig of FIG. **1**.
[0107] FIG. **15**A is an enlarged view of a portion of the hydraulic circuit of FIG. **15**.
[0108] FIGS. **16**A-**160** are schematic views of the drill rig of FIG. **1**, performing a drill cycle.
[0109] FIGS. **17**A-**17**H are schematic views of the drill rig of FIG. **1**, performing a resin cycle.
[0110] FIGS. **18**A-**18**M are schematic view of the drill rig of FIG. **1**, performing a bolt cycle.
[0111] FIG. **19** is a block diagram illustrating a controller of the drill rig of FIG. **1**.
[0112] FIG. **20** is a perspective view of an intrinsically safe position detector of the drill rig of FIG. **1**.
[0113] FIG. **21** is a perspective view of the intrinsically safe position detector of FIG. **20** while coupled to the carousel of FIG. **4**.
[0114] FIG. **22** is a plan view of the carousel of FIG. **4** showing a loaded state of the carousel.
[0115] FIG. **23** illustrates an example control panel of the drill rig of FIG. **1**.
[0116] FIG. **23**A illustrates an example button layout of the control panel of FIG. **23**.
[0117] FIG. **24** illustrates an example control panel of the drill rig of FIG. **1**.
[0118] FIG. **25** illustrates an example user interface during a drill operation of the drill rig of FIG. **1**.
[0119] FIGS. **26**A and **26**B illustrate an example user interface during a resin operation of the drill rig of FIG. **1**.
[0120] FIGS. **27**A and **27**B illustrate an example user interface during a bolt operation of the drill rig of FIG. **1**.
[0121] FIG. **28** is a flowchart of a method for operating the drill rig of FIG. **1** in an automatic mode.
[0122] FIG. **29** is a flowchart of a method for controlling a drill operation of the drill rig of FIG. **1** in an automatic mode.
[0123] FIG. **30** is a flowchart of a method for controlling a resin operation of the drill rig of FIG. **1** in an automatic mode.
[0124] FIG. **31** is a flowchart of a method for controlling a bolt operation of the drill rig of FIG. **1** in an automatic mode.
[0125] FIG. **32** is a flowchart of a method for controlling an error-handling operation of the drill rig of FIG. **1** in an automatic mode.

## DETAILED DESCRIPTION

[0126] Before any embodiments are explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The disclosure is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. Use of “including” and “comprising” and variations thereof as used herein is meant to encompass the items listed thereafter and equivalents thereof as well as

additional items. Use of “consisting of” and variations thereof as used herein is meant to encompass only the items listed thereafter and equivalents thereof. 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.

[0127] 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, aspects may be implemented in software (for example, stored on non-transitory computer-readable medium) executable by one or more processing units, such as a microprocessor, an application specific integrated circuits (“ASICs”), or another electronic device. 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 invention. For example, “controllers” described in the specification may include one or more electronic processors or processing units, one or more computer-readable medium modules, one or more input/output interfaces, and various connections (for example, a system bus) connecting the components.

[0128] With reference to FIGS. **1**-**3**, a drill rig **10** (i.e., a drilling rig, a bolting rig) is operable to drill or bolt into a work surface (e.g., a mine side wall, a mine roof, etc.). The drill rig **10** includes a storage or magazine assembly (e.g., carousel assembly **14**) that includes, as illustrated in FIG. **4**, consumables **18** (e.g., drill bits, bolts, resin cartridges, adaptors, expendables, self-drilling bolts, combined bolt-and-resin type bolts, extension drill rods, etc.) carried on a rotating magazine or carousel **22**. The drill rig **10** also includes a loading assembly **26** with a loading arm **30** that retrieves one of the consumables **18** from the carousel **22** and loads the consumable **18** into a driver, such as a drill head **34**. The drill head **34** and the consumable **18** are then fed or driven toward the work surface as the drill head **34** translates along a drill axis **36** on a track assembly **38**. The drill rig **10** includes a controller **40** and is capable of automated operation. In some embodiments, a complete drill cycle, resin cycle, and bolt cycle, for example, can be performed by the drill rig **10** consecutively without manual interaction with a human operator. As explained in greater detail below, the automated drill rig **10** provides improvements in overall efficiency, safety, and compactness.

[0129] With reference to FIGS. **3** and **4**, the carousel **22** of the carousel assembly **14** is rotatable about a carousel axis **42**. In the illustrated embodiment, the carousel assembly **14** includes a plurality of consumables **18** (e.g., drill bits **18**A, resin cartridges **18**B, bolts **18**C, adaptors **18**D, expendables, etc.) carried on the carousel **22**. The consumables **18** are of various sizes (i.e., different lengths, different diameters) and shapes. In the illustrated embodiment, the carousel assembly **14** includes six consumables **18**: one drill bit **18**A, two resin cartridges **18**B, two bolts **18**C, and an adaptor **18**D. In other embodiments, the carousel assembly **14** includes any number of consumables or types of consumables. In the illustrated embodiment, the carousel **22** is circular. In other embodiments, the carousel is non-circular (e.g., oval shaped). The carousel **22** is rotatable about the carousel axis **42** to place a desired consumable in a position that the loading assembly **26** can retrieve the desired consumable. In the embodiment illustrated in FIGS. **3** and **4**, the carousel **22** is shown with the drill bit **18**A in a loading position such that the loading assembly **26** can access the drill bit **18**A and load the drill bit **18**A into the drill head **34**. Other consumables can be rotated into the loading position as the carousel **22** is rotated.

[0130] With reference to FIG. **5**, an actuator **46** (e.g., a hydraulic actuator) is positioned within the carousel **22** and is aligned with carousel axis **42**. A sensor **50**, such as a position sensor, a rotary sensor, or the like is coupled to the hydraulic actuator **46** and is also aligned with the carousel axis **42**. In the embodiment illustrated in FIG. **5**, the sensor **50** is an encoder **50** (e.g., rotary encoder). In the illustrated embodiment, the actuator **46** and the encoder **50** are positioned coaxially with the

carousel axis **42**. Specifically, as illustrated also in FIG. **4**, the actuator **46** is positioned within a lower mast **54** of the carousel **22**, and the encoder **50** is positioned within a casing **58** (shown transparently in FIG. **5**). The encoder **50** may be optical, magnetic, or any other type of suitable sensor that is configured to detect the rotational position of the actuator **46** or the carousel **22**. The encoder **50** may further be configured to detect an axial or translational position of the actuator **46** and/or carousel **22**. In some embodiments, a plurality of actuators **46** may be positioned with the carousel **22**. The carousel **22** may be supported on the casing **58**, the actuator **46**, and/or lower mast **54** by a bearing or base rack **60** surrounding the actuator **46**.

[0131] With reference to FIGS. **6** and **9**B, the carousel assembly **14** further includes an arm or cam **62** (FIG. **9**B) supported on the carousel **22** for rotation therewith. In some embodiments, the cam **62** is supported on a post or pillar that is coupled to the carousel **22**. In the illustrated embodiment, the cam **62** is positioned above (e.g., relative an axially direction) the adaptor **18**D but may positioned axially below the adapter **18**D in other embodiments. When the adaptor **18**D is in the loading position (shown in FIG. **9**A), the cam **62** is positioned to engage a corresponding valve actuator **70** (FIG. **9**B) that is configured to actuate a hydraulic valve (e.g., a push button solenoid valve, a switch valve, etc.). In the illustrated embodiment, the valve actuator **70** is supported on a valve manifold **72** (see FIG. **9**B). The valve manifold **72** may also house and/or support fluid circuitry and multiple other valves, cylinders, reservoirs, or the like, such as a hydraulic valve.

[0132] In response to the valve actuator **70** being actuated (e.g., depressed) by the cam **62**, a valve may alter a fluid flow path of a hydraulic circuit. In the illustrated embodiment, actuating the valve actuator **70** causes a hydraulic circuit that is responsible for raising the loading arm **30** to be bypassed. In other words, actuating the valve actuator **70** may deactivate a portion of a hydraulic circuit that is responsible for a certain function (e.g., raising and lowering) of the loading assembly **26**. For example, engagement of the valve actuator **70** causes the loading arm **30** not to raise or lower but only rotate. Since the adaptor **18**D has a much shorter length than other consumables, bypassing the raising/lowering actuator of the loading assembly **26** may assist in transferring the adaptor **18**D to the feed and/or simplify the path for the loading arm. In the illustrated embodiments, the cam **62** is positioned toward an upper portion of the carousel **22**. In other embodiments, the cam **62** and the valve actuator **70** may be positioned at a lower or bottom portion of the carousel **22**.

[0133] With reference to FIG. **7**, a plurality of clip racks **74** are coupled to the carousel **22** at spaced locations along the carousel axis **42**. Each of the clip racks **74** is configured to receive a plurality of clips **78** positioned about the carousel axis **42** (see FIG. **5**). In the illustrated embodiment, the clips **78** are received within a recess **82** formed in the clip racks **74**. The consumables **18** are removably coupled to the clips **78** carried on the carousel **22**. In other words, the consumables **18** may be selectively attached or removed from the clips **78** by overcoming a biasing force. The clips **78** elastically deform to facilitate easy push-in and easy pull-out of the consumables **18** from the clips **78**. In some embodiments, the clips **78** could include a grasping member or moveable lock configured to hold the consumables **18** in the respective clip **78**.

[0134] With further reference to FIG. **7**, the clips **78** are at least partially received within the recess **82** and secured to the clip rack **74** by fasteners **86**. The clips **78** may be easily replaced or swapped out from the clip rack **74** according to the desired number and type of consumables **18** or as the clip **78** wears out. In the illustrated embodiment, the fasteners **86** are threaded bolts. In other embodiments, another type of fastener (e.g., lock bolt, nut, screw, magnet, clamp, etc.) may be used.

[0135] With reference to FIG. **8**, the clip **78** includes a base **90** and a deflectable finger **94** that defines an opening **98** in which to receive the consumable **18**. In some embodiments, the base **90** and the finger **94** are formed from an elastically deformable material, such as an elastically deformable plastic. The base **90** includes two apertures **102** configured to receive the fasteners **86** (see FIG. **7**) that secure the clip **78** to the clip rack **74** when the base **90** of the clip **78** is positioned

within the recess **82** (see FIG. **7**). The clip **78** also includes wear strips **106** that are positioned adjacent the opening **98**. The wear strips **106** provide a durable surface against which the consumable **18** may slide when moving in and out of the opening **98**. In the illustrated embodiment, the clip **78** includes two wear strips **106** that are molded within the base **90** and the finger **94** (i.e., insert molded), and the wear strips **106** may be formed of spring steel. The wear strips **106** protect the base **90** and the finger **94** from excessive wear during normal operation. In other constructions, one or more wear strips **106** are omitted and the clip **78** itself is formed of or with a similar durable surface to that of the wear strips **106**. In some embodiments, the wear strips **106** may provide additional elastic gripping force.

[0136] During operation of the carousel assembly **14**, the actuator **46** can be activated by the controller **40** based on feedback from the encoder **50** to rotate the carousel **22** about the carousel axis **42**. The carousel **22** is positioned in a desired orientation (e.g., an indexed position) to place the desired consumable **18** in the loading position, in which the desired consumable can be retrieved by the loading assembly **26**. As illustrated in FIG. **9**B, when the carousel **22** is positioned with the adaptor **18**D in the loading position, the cam **62** engages the valve actuator **70** to deactivate a portion of hydraulic circuit of the loading assembly **26**. The consumables **18** are selectively coupled to the carousel **22** by the clips **78** and are released from the carousel **22** when the loading assembly **26** overcomes the threshold force required to deflect the finger **94**, thereby releasing the consumable **18** from the carousel **22**. Further detail of the carousel assembly **14** operation is described below in reference to the overall operation of the drill rig **10**.

[0137] With specific reference to FIGS. **1** and **9**A-**11**B, the drill rig **10** includes a washer loader assembly **110** configured to load a washer **114** onto a consumable **18** (e.g., a drill bit **18**A). The washer loader assembly **110** includes a plurality of washers **122** (see FIG. **10**) stored at an axial end **118** (e.g., an upper end) of the carousel assembly **14**, forming a stack of washers **122**. The stack of washers **122** is aligned (i.e., coaxial) with the carousel axis **42**. In the illustrated embodiment, the stack of washers **122** is positioned on a plate **126** positioned adjacent an upper end of the carousel **22**.

[0138] As illustrated in FIGS. **1-3** and **9**A-**11**B, the washer loader assembly **110** also includes a carrier arm **130** that is configured to move a single washer **114** from the stack of washers **122** and position the washer **114** co-axially with the consumable **18** that is coupled to the loading assembly **26**, as explained in greater detail below.

[0139] With specific reference to FIG. **10**, the carrier arm **130** is coupled at a first end **134** to an actuator **138**. The actuator **138**, along with the carrier arm **130**, is configured to extend and rotate with respect to a fixed casing **142** (see also FIG. **9**A). Specifically, the actuator **138** defines an axis **146** along which the actuator **138** extends and about which the actuator **138** rotates. In the illustrated embodiment, a support post or sleeve **150** is positioned between the casing **142** and the actuator **138**. The sleeve **150** includes a groove **154** that captures a corresponding pin **158** formed on the actuator **138**. As the actuator **138** is extended from the casing **142**, the pin **158** moves within the groove **154**.

[0140] In the illustrated embodiment, the sleeve **150** may is a two-piece sleeve that includes a first sleeve (e.g., an upper sleeve) **150**A and a second sleeve (e.g., a lower sleeve) **150**B with the groove **154** extending in the upper and lower sleeves **150**A, **150**B. The groove **154** includes a flair **156** that allows for minor relative rotation between the sleeves **150**A, **150**B. The flair **156** may have a generally diamond shape and be disposed at a junction **157** between the first sleeve **150**A and the second sleeve **150**B. In the illustrated embodiment, the sleeves **150**A, **150**B are allowed to rotate by approximately (+/−) 5-degrees relative one another. Providing minimal relative rotation between the sleeves **150**A, **150**B allows for separate positional adjustments of the first sleeve **150**A and the second sleeve **150**B. Hydraulics may be applied to the sleeve **150** to improve control during movement of the actuator **138** and the arm **130**.

[0141] With continued reference to FIG. **10**, the groove **154** includes a linear portion **162** and a

curved portion **166** position on either side of the flair **156**. As the pin **158** moves along the linear portion **162** of the groove **154**, the actuator **138** extends away from the casing **142**, translating along the axis **146**. As the pin **158** moves along the curved portion **166** of the groove **154**, the actuator **138** extends away from the casing **142** along the axis **146** and rotates relative to the casing **142** about the axis **146**. The flair **156** allows the pin **158** to slightly deviate from the linear portion **162** and the curved portion as it passes between the sleeves **150**A, **150**B. In other words, the actuator **138** extends and rotates simultaneously as the pin **158** moves past the flair **156** and through the curved portion **166** of the groove **154** in the sleeve **150**. As a result, the carrier arm **130** is raised away from and rotated relative to the stack of washers **122** upon activation of the actuator **138**. In the illustrated embodiment, a position of the groove **154** above the flair **156** can be adjusted relative a position of the groove **154** below the flair **156** to thereby adjust a starting or ending position of the carrier arm **130**.

[0142] With reference to FIGS. **10** and **11**, the carrier arm **130** includes a forked portion **170** positioned at a second end **174**, opposite the first end **134**. The forked portion **170** defines an opening **178** through which one of the consumables **18** may pass, as explained in greater detail below. The carrier arm **130** also includes one or more magnets **182** (i.e., a magnetic coupling) positioned adjacent a surface **186** that faces the stack of washers **122**. In the illustrated embodiment, the magnets **182** are permanent magnets positioned within one or more recessed portions **183** on the arm **130**. In other embodiments, the magnets **182** are permanent magnets positioned adjacent to the opening **178**.

[0143] During operation of the washer loader assembly **110**, the magnet **182** on the carrier arm **130** is capable of magnetically coupling one of the washers from the stack **122** to the carrier arm **130**. The carrier arm **130** is then raised and rotated by the actuator **138** to reposition the single washer **114** from a stored position on the stack of washers **122** to a mounting position. In the mounting position, the washer **114** is aligned with a consumable **18** carried by the loading assembly **26** and is configured to receive the consumable **18** controlled by the loading assembly **26** (e.g., FIG. **16**D-**16**F). In other words, with the washer **114** in the mounting position (FIG. **16**D), the consumable **18** is translated by the loading assembly **26** through a central aperture in the washer **114** (FIG. **16**E). The loading assembly **26** then moves the consumable **18** and the washer **114** away from the carrier arm **130**, thereby breaking the magnetic coupling between the carrier arm **130** and the washer **114** (FIG. **16**D-**16**F). As the consumable **18** and the washer **114** move away from the carrier arm **130**, the consumable **18** moves through the opening **178** formed in the carrier arm **130**.

[0144] With reference to FIGS. **2**, **9**A, and **11**B, a balance rod **190** is coupled to the loading assembly **26** and is configured to support the washer **114** once the washer **114** has been loaded onto the drill bit **18**A. As described in greater detail below, the balance rod **190** supports the washer **114** in position on the drill bit **18**A as the loading assembly **26** moves the drill bit **18**A and until the drill bit **18**A has been coupled to the drill head **34**. Once the drill bit **18**A has been coupled to the drill head **34**, the washer **114** is received within a recess **194** formed in a top plate **198** of the drill rig **10**. The top plate **198** includes an opening or bore **200** through which the consumable may be driven. The drill axis **36** is aligned with the bore **200**. In the illustrated embodiment, the recess **194** is circular shaped and is aligned with the drill axis **36**. The top plate **198** and the recess **194** include a section **202** that has been removed (i.e., a cut-out) in order to allow the consumable **18** to translate in and out of the bore of the top plate **198**.

[0145] As such, the washer **114** is automatically loaded onto the drill bit **18**A during a drill cycle (FIG. **16**A-**160**) of the drill rig **10**. The drill rig **10** therefore automates the addition of the washer **114** to the consumable **18**A, which would otherwise be loaded manually onto the consumable. The drill rig **10** also maintains the ability to override or temporarily halt operation of the washer loader **110** to selectively allow an operator the ability to load and/or unload a washer **114** on/from the consumable **18**A.

[0146] As explained in more detail below, the washer loader assembly **110** automatically loads a

washer **114** onto a desired consumable **18**A, but not onto other consumables **18**B, **18**C, **18**D that do not require a washer. The washer **114** is supported on the consumable **18**A by the balance rod **190** until the consumable **18**A is loaded in the drill head **34** and the washer **114** is received within the recess **194** formed in the top plate **198**.

[0147] With reference to FIGS. **12**A-**12**D, an alternate washer loader assembly **110***a* usable with the drill rig **10** obviates the need for the balance rod **190** coupled to the loading assembly **26**. Rather than the balance rod **190** positioned on the loading assembly **26** to temporarily support the washer **114**, the washer **114** is centered on the consumable **18**A before the consumable **18**A is centered in the drill head **34**. Other than the balance rod **190** being obviated, the alternate washer loader assembly **110***a* operates in a similar or common manner as the washer loader assembly **100**, as described below.

[0148] FIG. **12**A illustrates the alternate washer loader assembly **110***a* in a loading position, in which a loading arm **130***a* of the alternate washer loader assembly **110***a* is extended along a washer loader axis **112**.

[0149] FIG. **12**B illustrates the alternate washer loader assembly **110***a* in a lifted position, in which the loading arm **130***a* of the alternate washer loader assembly **110***a* is extended along the washer loader axis **112** and lifted along a washer loader axis **146***a*. The loading arm **130***a* is lifted above an upper end of the consumable **18**A supported on the carousel **22**.

[0150] FIG. **12**C illustrates the alternate washer loader assembly **110***a* in a lifted and retracted position, in which the loading arm **130***a* of the alternate washer loader assembly **110***a* is retracted along a washer loader axis **112** relative the extended position. The loading arm **130***a* remains lifted above an upper end of the consumable **18**A such that, as the loading arm **130***a* is retracted, a center of the washer **114** passes over a center of the consumable **18**A. The consumable **18**A is offset relative the washer **114** such that retracting the loading arm **130***a* centers the washer **114** over the consumable **18**A.

[0151] FIG. **12**D illustrates the alternate washer loader assembly **110***a* in a bit receiving position, in which the loading arm **130***a* of the alternate washer loader assembly **110***a* is retracted along the washer loader axis **112** and lifted along the axis **146***a*. FIG. **12**D further illustrates the consumable **18**A lifted into the washer **114**. The alternate washer loader assembly **110***a* further includes a guide protrusion **113** that extends from the alternate washer loader assembly **110***a* adjacent the loading arm **130***a*.

[0152] As shown in FIGS. **12**A-**12**D, the guide protrusion **113** is partially curved to generally correspond to the curved movement of the loading assembly **26**. The guide protrusion **113** is positioned on the alternate washer loader assembly **110***a* such that the washer **114** is guided into the drill head **34** as the loading assembly **26** rotates the consumable **18**A and washer **114** out of/away from the loading arm **130***a*. In other words, the guide **113** extends far enough away from the loading arm **130***a* such that the washer **114** does not fall down the consumable **18**A past the drill head **34**.

[0153] With reference to FIGS. **13**A, **13**B, and **14**A, the loading assembly **26** is illustrated with the loading arm **30** positioned adjacent the carousel assembly **14**. Specifically, the loading arm **30** can be positioned adjacent to the consumables **18** (e.g., adaptor **18**D) carried on the carousel **22** while in the loading position. The loading assembly **26** includes a first actuator **206** configured to raise and lower the loading arm **30** and a second, separate actuator **210** configured to rotate the loading arm **30**. The first actuator **206** defines a first axis **214** and the second actuator **210** defines a second axis **218**. In the illustrated embodiment, the first axis **214** is spaced apart and oriented parallel to the second axis **218**. The first actuator **206** and the second actuator **210** allows for the loading arm **30** to be raised and lowered independently of rotation. In other words, the loading arm **30** can be raised or lowered (i.e., translated along the first axis **214**) without being rotated (i.e., rotated about the second axis **218**). Likewise, the loading arm **30** can be rotated about the second axis **218** without being raised or lowered along the first axis **214**. Independent control of the loading arm **30**

movement offers greater flexibility in controlling the loading assembly **26** to perform various tasks.
[0154] With continued reference to FIG. **13**A, the loading arm **30** has a fixed length. The loading arm **30** does not need to be extended in order to move the consumables **18** from the carousel **22** or to load the consumable **18** into the drill head **34**. In other words, a separate actuator is not required to translate the loading arm in a direction transverse to the second axis **218**. Stated another way, the distance between the drill head **34** and the second axis **218** is equivalent to the distance between the consumables **18** in the loading position on the carousel **22** and the second axis **218**. As such, a distance between the drill head **34** and the second axis **218** is equal to the distance between the second axis **218** and the carousel assembly **14**.
[0155] With reference to FIGS. **13**B and **14**A, the loading arm **30** includes two clamp plates **222** that are configured to move between an open position (FIGS. **13**B and **14**A) and a closed position, where the clamp plates **222** are positioned around and secured to the consumable **18**. In the illustrated embodiment, each clamp plate **222** includes a groove **226** in which to receive the consumable **18** when in the closed position. The movement of the clamp plates **222** and the shape of the grooves **226** in the clamp plates **222** are configured to capture consumables having a variety of diameters. The loading arm **30** also includes a sensor **230** (see FIG. **14**A) positioned adjacent the clamp plates **222**. As shown in FIG. **13**B, a clamp actuator **225** may be operated to move the clamp plates **222**, as detailed below. In some embodiments, the actuator **210** may be operated to move the clamp plates **222**.
[0156] Referring to FIG. **13**B, the clamp actuator **225** is operable to drive a piston that is positioned in an actuator housing **225***b*. A rod of the piston **225***a* is secured to a coupling plate **225***d* (e.g., by a bolt having a head **225***c*). The coupling plate **225***d* is coupled to the clamp plates **222** by a linkage **225***e* by, for example, one or more couplers **225***f*. The linkage or bar arrangement of the plate **225***d*, linkage **225***e*, and clamp plate **222** translates linear or axial movement of a part of the actuator **225** (e.g., the piston **225***a*) into rotational movement of the clamp plates **222**. In the illustrated embodiment, the plate **225***d* is coupled to both clamp plates **222**. In some embodiments, more than one linkage **225***e* may be coupled between the plate **225***d* and the clamp plate **222**.
[0157] In some embodiments, as shown in FIG. **14**B, pressurized fluid may be provided to an actuator on loading arm (e.g., the actuator for moving clamp plates **222**) by a fluid coupling **232**. The loading arm **30** is supported for rotation relative to the fluid coupling **232** such that lubricant supply hoses do need to rotate with the loading arm **30**. Rather, the fluid coupling **232** supports a lubricated bearing or cone shape that accommodates delivery of fluid to a rotational part of the clamp plates **222** and loading arm **30**. The fluid coupling **232** includes a plurality of cavities **232***a*, such as tunnels, galleries, or the like. The cavities **232***a* are positioned around a circumference of the fluid coupling **232** to supply fluid to the loading arm **30**. In the illustrated embodiment, the cavities **232***a* extend radially outwardly and are positioned around approximately half of an outer circumference of the fluid coupling **232**. In other embodiment, the cavities **232***a* are positioned around more than half (e.g., 75%, 100%, etc.) of the outer circumference of the fluid coupling **232**. In some embodiments, the cavities **232***a* are capped or plugged at one end and pressurized to provide pressurized fluid to loading arm **30** and clamp actuator **225**. The loading arm **30** includes a plurality of complementary receptacles configured to receive fluid from the cavities **232***a*. In other words, the cavities **232***a* on the fluid coupling **232** provide a first port and the complementary receptacles on the loading arm **30** provides a second port to maintain fluid communication with the first port throughout the rotational motion of the loading arm **30**. A lubricant may be provided to components on the loading arm **30** in a similar manner.
[0158] As illustrated in FIGS. **14**B and **14**C, a portion of the loading arm **30** may be supported by a key arrangement **233** that accommodates sliding movement (e.g., along the axis **218**) of the loading arm **30**. The key arrangement **233** includes a support mast or axially fixed shaft **233***a*, two keys **233***b* receivable in a portion of the support mast **233***a*, and an inner shaft **233***c* that is received in the support mast **233***a* and axially moveable (e.g., slidable) relative, for example, the oil coupling

**232**. The keys **233***b* are retained to the support mast **233***a* by a carrier **233***d*, such as, for example, a split band wear carrier **233***d*. The carrier **233***d* is a two-piece carrier that supports one or more wear bands **233***e*. The keys **233***b* are sized and shaped to contact a grooved surface on the inner shaft **233***c* to prevent relative rotation between the support mast **233***a* and the inner shaft **233***c*. The keys **233***b* thus support axial movement of the loading arm **30** and prevent wear or damage between the shaft **233***a*, **233***c* during movement.

[0159] The loading arm **30** is further supported for rotation on an outer shaft **233***g* that slides with the inner shaft **233***c*. In the illustrated embodiment, the inner and outer shafts **233***c*, **233***g* do not move axially relative one another, and both shafts **233***c*, **233***g* move axially relative the support mast **233***a*. The outer shaft **233***g* particularly support rotation of the loading arm **30** through the wear bands **233***e* that surround the wear band carrier **233***d*. The wear bands **233***e* contact the outer shaft **233***g* and accommodate protected relative rotation between the keys **233***b* and the loading arm **30** on the outer shaft **233***g*. In other words, the wear bands **233***e* assist in preventing wear (e.g., between abrasive or touching surfaces) in the loading assembly **26** as the loading arm **30** is rotated or translated. During installation of the key arrangement **233**, the keys **233***b* are inserted into the support mast **233***a*, and the portions of the carrier **233***d* are positioned around the keys **233***b*. The wear bands **233***e* are pressed or forced over the carrier **233***d* to hold the bands **233***e*, the carrier **233***d*, and the keys **233***b* to the support mast **233***a*.

[0160] In the illustrated embodiment, the wear bands **233***e* are made of a polymer, such as polyester. The wear band carrier **233***d* is made of metal, such as cast iron, steel, stainless steel, or the like. In other embodiments, the wear band carrier **233***d* is made of a rigid polymer. In the illustrated embodiment, the carrier **233***d* is made of steel. The keys **233***b* are also made of a metal, such as brass, copper, aluminum, or the like. In the illustrated embodiment, the keys **233***b* are brass.

[0161] In the illustrated embodiment, the sensor **230** is a proximity sensor that detects when the consumable **18** is gripped by the loading arm **30** (i.e., positioned between the clamp plates **222**). In some embodiments, the sensor **230** is an inductive sensor detecting a presence of a metallic material. The two clamp plates **222** are moved between the open position and the closed position using the clamp actuator **225** (see FIG. **14**A), for example, a hydraulic actuator, a motor, a solenoid, or the like. The clamp actuator **225** is part of the drive motors and actuators **332** controlled by the controller **40**, as described in detail below.

[0162] With reference to FIG. **15**, the drill rig **10** includes a hydraulic circuit **234** to power various functionality on the drill rig **10**. The hydraulic circuit **234** includes a main pressure source **238** and a main return **242**. The hydraulic circuit **234** also includes a function-select hydraulic line **246** and a hydraulic return **250** (i.e., a second hydraulic return). The hydraulic circuit **234** also includes main flow valves **254** and diversion valves **258** that are fluidly coupled to a hydraulic function **262** on the drill rig **10**. In some embodiments, the hydraulic function **262** includes index tilt left/right; carousel rotate; index tilt fore/aft; rotate loading arm; raise/lower loading arm; open/close jaws; washer loader; auxiliary functions, or any other suitable hydraulic function on the rig **10**. The hydraulic functions **262** can include various hydraulic components, for example: actuators; cylinders; hydraulic motors; pressure compensation valves; and check valves.

[0163] With continued reference to FIG. **15**, the hydraulic functions **262** are paired together to create a hydraulic sub-circuit **266** that includes a primary hydraulic function **270** and a secondary hydraulic function **274**. The main pressure source **238** and the main return **242** fluidly communicate with each of the hydraulic sub-circuits **266** in parallel. The second hydraulic return **250** is fluidly coupled to each of the diversion valves **258**. Likewise, the function-select hydraulic line **246** is fluidly coupled to each of the diversion valves **258**. In the illustrated embodiment, the main flow valves **254** are three-position, solenoid-actuated, electronically controlled hydraulic valves. In the illustrated embodiment, the diversion valves **258** are two-position, hydraulic valves with a spring-biased neutral position.

[0164] With reference to FIG. **15**A, each hydraulic sub-circuit **266** includes a first diversion valve

**258**A, a second diversion valve **258**B, and a main flow valve **254**. An input side **278** of the main flow valve **254** is connected to the main pressure source **238** and the main return **242**. The main flow valve **254** has a closed neutral position and is electronically controlled by a solenoid between two open positions to provide directional control of the hydraulic function **262**. For example, the main flow valve **254** is controlled to move to a first open position to rotate the carousel **22** in a first direction about the carousel axis **42** (e.g., clockwise) and the main flow valve **254** is controlled to move to a second open position to rotate the carousel **22** in a second direction, opposite the first direction (e.g., counter-clockwise). An output side **282** of the main flow valve **254** are in fluid communication with an inlet side **286** of both the first diversion valve **258**A and the second diversion valve **258**B. The second hydraulic return **250** is also fluidly communicating with the inlet side **286** of the first diversion valve **258**A and the second diversion valve **258**B. An output side **290** of each of the diversion valves **258** is fluidly coupled to both the primary hydraulic function **270** and the secondary hydraulic function **274**.

[0165] With continued reference to FIG. **15**A, the diversion valves **258** have a first, spring-biased open position and a second open position. The position of the diversion valve **258** is determined by the pressure in the function-select hydraulic line **246**. For example, when the pressure in the function-select hydraulic line **246** is low or near atmosphere, the first diversion valve **258**A and the second diversion valve **258**B are spring-biased into the first open position, as illustrated in FIG. **15**A, thereby activating the primary hydraulic function **270** and deactivating the secondary hydraulic function **274**. On the other hand, when the pressure in the function-select hydraulic line **246** is higher, the first diversion valve **258**A and the second diversion valve **258**B are forced into the second open position (against the spring bias), thereby activating the secondary hydraulic function **274** and deactivating the primary hydraulic function **270**. In other words, the pressure in the function-select hydraulic line **246** is toggled high and low to determine whether the primary function **270** or the secondary function **274** is activated by being placed in fluid communication with the main pressure source **238** and the main return **242**. The deactivated hydraulic function is placed in fluid communication with the second hydraulic return **250** to release any stored pressure. In some embodiments, the two diversion valves **258**A and **258**B are combined into a single six-way, two-position direction control valve (e.g., the Model: KVH-6/2-8 directional valve available from Porclain Hydraulics or the Model: DNDY valve available from Sun Hydraulics).

[0166] The diversion valves **258** are small and therefore reduce the overall size of the drill rig **10**. In other words, the diversion valves **258** are smaller than an additional solenoid operated directional control valve, which also requires an additional solenoid and electrical components. In addition, the diversion valves **258** are hydraulically actuated by the function-select hydraulic line **246** and are not electronically controlled, thereby reducing the complexity of the electronics. In other words, the diversion valves **258** replace electronically controlled solenoid valves. A single solenoid-actuated flow valve **254** can fluidly communicate the main pressure source **238** and the main return **242** to two different hydraulic functions (i.e., the primary function **270** and the secondary function **274**). In this sense, the hydraulic circuit **234** provides a dual-functionality for each of the flow valves **254**.

[0167] With reference to FIGS. **16**A-**160**, FIGS. **17**A-**17**H, and FIGS. **18**A-**18**M a complete, automated operation cycle of the drill rig **10** is illustrated. In the illustrated embodiment a complete, automated operation cycle includes a drill cycle (FIGS. **16**A-**160**), a resin cycle (FIGS. **17**A-**17**H), and a bolt cycle (FIGS. **18**A-**18**M). The drill rig **10** automatically performs the drill cycle, followed by the resin cycle, followed by the bolt cycle. In other embodiments, the drill rig **10** may perform any number of desired cycles and in any desired sequence, and/or only some of the cycles may be performed. In the illustrated embodiment, a working surface **294** is a roof of an underground mine. As explained above, the working surface may also be a wall of an underground mine, for example, and the drill rig **10** can be oriented accordingly. In other words, the drill rig **10** is operable while positioned in more than one orientation (e.g., both an up-down vertical

orientation and a left-right horizontal orientation)
[0168] With reference to FIGS. **16**A-**160**, the drill cycle of the drill rig **10** is illustrated. FIG. **16**A illustrated the drill rig **10** in a starting position relative to the working surface **294**. In the starting position, the drill head **34** is positioned to receive the consumable **18**, and the top plate **198** is retracted.
[0169] FIG. **16**B illustrates the consumables **18** and the washers **114** (e.g., stack of washers **122**) being loaded into the carousel assembly **14** and drill rig **10**.
[0170] FIG. **16**C shows the drill rig **10** moving to a start position after being loaded with the consumables **18** and the washer **114**. The actuator **138** of the washer loader assembly **110** retracts and rotates such that the carrier arm **130** magnetically engages with a washer **114**. The carousel assembly **14** is rotated to position the desired consumable (i.e., the drill bit **18**A) into the loading position such that it can be loaded into the loading arm **30**.
[0171] FIG. **16**D illustrates the washer loader assembly **110** with the actuator **138** and the carrier arm **130** extended and rotated. The carrier arm **130** holds the washer **114** in a position that is aligned with the drill bit **18**A, which is now secured to the loading arm **30**.
[0172] FIG. **16**E illustrates that the loading arm **30** and the drill bit **18**A are extended along the axis **214** (i.e., raised) such that the drill bit **18**A passes through the center aperture of the washer **114**.
[0173] FIG. **16**F illustrates the loading arm **30** and the drill bit **18**A with the washer **114** rotated about the second axis **218** such that the drill bit **18**A is aligned with the drill head **34**.
[0174] FIG. **16**G illustrates the drill head **34** translated along the drill axis **36** in order to receive the drill bit **18**A within the drill head **34** (i.e., within a chuck). During the steps shown in FIGS. **16**F-**16**G, the balance rod **190** contacts the washer **114** and maintains the washer **114** in position with respect to the drill bit **18**A.
[0175] FIGS. **16**H-**16**J illustrate the drill bit **18**A, the drill head **34**, and the top plate **198** translating along the drill axis **36** such that the drill bit **18**A drills a hole into the working surface **294** and the top plate **198** with the washer **114** abuts the working surface **294**.
[0176] FIGS. **16**K-**160** illustrate the end of the drill cycle where the drill bit **18**A and drill head **34** are retracted away from the working surface **294** and the drill bit **18**A is returned to the carousel **22** by the loading arm **30**. In the illustrated embodiment, the top plate **198** and the washer **114** remain abutted against the working surface **294** at the end of the drill cycle (FIG. **160**).
[0177] FIGS. **17**A-**17**H illustrate the resin cycle of the drill rig **10**. The resin cycle is similar to the drill cycle but with a resin cartridge **18**B instead of a drill bit **18**A being selected from the carousel assembly **14** by the loading arm **30**. In other words, the loading arm **30** moves the resin cartridge **18**B from the carousel assembly **14** to the drill head **34** (FIGS. **17**A-**17**D); the resin cartridge **18**B is inserted into the working surface **294** (FIGS. **17**E-**17**F); and the resin cartridge **18**B is returned to the carousel assembly **14** by the loading arm **30** (FIGS. **17**G-**17**H). Before the resin cartridge **18**B is returned to the carousel assembly **14**, resin is ejected from the resin cartridge **18**B and into the hole drilled by the drill bit **18**A. The resin may be ejected from the resin cartridge **18**B by a resin inserter or ejector. In the illustrated embodiment, a fluid such as water, oil, a water-oil mixture, or the like is pressurized in the inserter to eject or press the resin from the resin cartridge **18**B.
[0178] FIGS. **18**A-**18**M illustrate the bolt cycle of the drill rig **10**. The bolt cycle is similar to the drill cycle but with a bolt **18**C (and optionally, the adaptor **18**D) instead of a drill bit **18**A being selected from the carousel assembly **14** by the loading arm **30**. First, the bolt **18**C is loaded into the drill head **34** and partially inserted into the working surface **294** (FIG. **18**A-**18**E). Next, the drill head **34** is retracted with the bolt **18**C remaining in position (FIG. **18**F). In the illustrated embodiment, the bolt **18**C is held in place by the top plate **198**. In some embodiments, the top plate **198** includes a clamp that holds the bolt **18**C in position. The loading arm **30** then moves the adaptor **18**D from the carousel **22** to the drill head **34** (FIGS. **18**G-**18**I).
[0179] The loading arm **30** does not raise or lower when loading the adaptor **18**D because the cam **62** and valve actuator **70** disengage the first actuator **206**. Instead, the drill head **34** is moved to

accommodate loading the adaptor **18**D into the drill head **34** and the adaptor **18**D is held in position. Then, the adaptor **18**D is used to complete the insertion of the bolt **18**C into the working surface **294** (FIGS. **18**J-**18**K), and the adaptor **18**D is returned to the carousel **22** (FIGS. **18**L-**18**M). In some embodiments, the bolt **18**C may be loaded and driven by the drill head **34** without use of the adaptor **18**D.

[0180] The drill rig system **300** and the controller **40** are illustrated in greater detail with respect to FIG. **19**. The controller **40** is electrically and/or communicatively connected to a variety of modules or components of the drill rig system **300**. For example, the controller **40** may be connected to a user interface **304**, a consolidated controller **306**, a network switch **308** (via consolidated controller **306**), a central controller **312** (via network switch **308**), a network **316** (via network switch **308**), a power supply module **320** (e.g., an AC power supply module receiving AC mains power), one or more sensors **324** related to the drill rig system **300**, a database **328** (e.g., for storing data, images, and/or video related to the drill rig system **300**, component profiles, etc.), and/or one or more drive motors and actuators **332** of the drill rig system **300**.

[0181] The one or more drive motors and actuators **332** include one or more of the motors and actuators of the drill rig **10**. For example, the one or more drive motors and actuators **332** include the actuator **46** (i.e., a first actuator) configured to rotate the carousel **22**, the actuator **138** (i.e., a second actuator) configured to extend and rotate the carrier arm **130** with respect to the fixed casing **142**, the actuator **206** (i.e., a third actuator) configured to raise and lower the loading arm **30**, the actuator **210** (i.e., a fourth actuator) configured to rotate the loading arm **30**, and the clamp actuator **225** (i.e., a fifth actuator) to open and close the clamps **222**. The sensors **324** may include one or more sensors of the drill rig **10**. For example, the sensors **324** may include the encoder **50** configured to detect the rotational position of the carousel **22** and the sensor **230** to detect a consumable proximate the loading arm **30**. In addition to the encoder **50** and the sensor **230**, the sensors **324** may include a feed pressure sensor, a fine feed speed sensor, a rotation pressure sensor, a rotation speed sensor, an inclinometer, and/or a flow sensor.

[0182] The controller **40** includes combinations of hardware and software that are operable to, among other things, control the operation of the drill rig **10**, communicate with a central controller **312** or over the network **316**, among other functions. In some embodiments, the controller **40** includes a plurality of electrical and electronic components that provide power, operational control, and protection to the components and modules within the controller **40** and/or drill rig **10**. For example, the controller **40** includes, among other things, a processing unit **336** (e.g., a microprocessor, a microcontroller, or another suitable programmable device), a memory **340**, input units **344**, and output units **348**. The processing unit **336** includes, among other things, a control unit **352**, an arithmetic logic unit ("ALU") **356**, and a plurality of registers **360** (shown as a group of registers in FIG. **19**), and is implemented using a known computer architecture (e.g., a modified Harvard architecture, a von Neumann architecture, etc.). The processing unit **336**, the memory **340**, the input units **344**, and the output units **348**, as well as the various modules connected to the controller **40** are connected by one or more control and/or data buses (e.g., common bus **364**). The control and/or data buses are shown generally in FIG. **19** for illustrative purposes.

[0183] The memory **340** is a non-transitory computer readable medium and includes, for example, a program storage area and a data storage area. The program storage area and the data storage area can include combinations of different types of memory, such as a ROM, a RAM (e.g., DRAM, SDRAM, etc.), EEPROM, flash memory, a hard disk, an SD card, or other suitable magnetic, optical, physical, or electronic memory devices. The processing unit **336** is connected to the memory **340** and executes software instructions that are capable of being stored in a RAM of the memory **340** (e.g., during execution), a ROM of the memory **340** (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 drill rig **10** can be stored in the memory **340** of the controller **40**. The software includes, for example, firmware, one or more applications, program

data, filters, rules, one or more program modules, image processing software, and other executable instructions. The controller **40** is configured to retrieve from the memory **340** and execute, among other things, instructions related to the control processes and methods described herein. In other constructions, the controller **40** includes additional, fewer, or different components. In some embodiments, the software included in the implementation of the drill rig **10** can be stored in a memory of the central controller **312**. In such embodiments, the central controller **312** is configured to retrieve from the memory and execute instructions related to the control processes and methods described herein.

[0184] In mining environments, electrically components are desired to be intrinsically safe. For a device to be certified as intrinsically safe, every electrical element of the device is to perform according to the intrinsically safe standard specified. Rotary encoders present a roadblock for such certification. Multi-turn and optical encoders, which are typically used in mining equipment, are too large to and difficult to configure to be intrinsically safe. One alternative solution to multi-turn and optical encoders is to use mechanical encoders that do not use electrical components. However, mechanical encoders are not generally reliable, experience wear and tear, and are faced with coupling alignment and fitment issues.

[0185] FIG. **20** illustrates an intrinsically safe rotary encoder **50** configured to detect the rotational position of the carousel **22**. In the example illustrated, the intrinsically safe rotary encoder **50** is a magnetic position sensor including one or more Hall-effect sensors that detect a permanent magnet attached to the carousel **22**. As shown in FIG. **20**, the encoder **50** includes a position sensor **384** (e.g., Hall sensor) on a top portion of a housing **392**. The housing **392** is formed from a protective material configured to house the position sensor **384**. In some embodiments, the housing **392** is a stainless steel or other metal housing configured to arrest any flames or cut-off oxygen supply to any flame generated within the housing. Magnetic rotary encoders provide a significant temperature advantage over multi-turn and optical encoders. Hall sensor outputs operate at a power level of below 1 Watt (W) with minimal heat loss. Such low levels of power generate minimal heat making it easier to meet the intrinsically safe limitations. Although magnetic rotary encoders provide a significant advantage over other types of encoders, magnetic rotary encoders are currently not extensively used in the mining industry. The magnetic rotary encoder provides a contactless position detection mechanism. Magnetic encoders need to be positioned very close to a sensed element to provide accurate measurements. Additionally, the output signals provided by generally available Hall sensors are not compatible with the communication and sensing techniques used by a control system of a mining machine.

[0186] To overcome the above challenges, the position sensor **384** is exposed from the housing **392** such that the position sensor **384** can be placed in close contact with a magnet of the carousel. Specifically, the position sensor **384** is provided outside a periphery of the housing **392**. With reference to FIG. **21**, the intrinsically safe rotary encoder **50** is provided at a bottom of the carousel **22**. In some embodiments, the rotary encoder **50** may be provided at a top of the carousel **22**. The housing **392** of the rotary encoder **50** is fixed to a housing of the carousel **22** using fasteners. A gasket or seal may be provided between the rotary encoder **50** and the carousel **22** to provide an air-tight and/or water-tight seal between the rotary encoder **50** and the carousel **22**. As discussed above, the position sensor **384** is exposed from the housing **392** such that the position sensor **384** extends into a housing of the carousel **22**. The rotary encoder **50** is fixed to the carousel such that the position sensor **384** is in close proximity to a magnet fixed to a rotary shaft of the carousel **22**. The magnet includes at least two poles (one North and one South), which are detected by the position sensor **384**. The detection signals are then forwarded to the controller **40** to indicate a rotary position of the carousel **22**. In some embodiments, the magnet may include additional poles (e.g., two or more North and two or more South) to provide additional granularity in rotation position measurement. In some embodiments, the position sensor **384** may be provided within the periphery of the housing **392** and the magnet of the carousel can be extended into the housing **392**

of the rotary encoder **50** to place the magnet in close proximity to the position sensor **384**.
[0187] Depending on the type of magnetic encoder used, the rotary encoder **50** may provide an analog output, a pulse-width modulated (PWM) output, a serial peripheral interface output, and the like. Accordingly, an analog to digital converter (ADC) or a Universal Asynchronous Receiver-Transmitter (UART) to convert the output signal from one form (e.g., analog) to another form (UART) such that the rotary encoder **50** may be integrated with other components of the drill rig **10**.
[0188] FIG. **22** illustrates an exemplary configuration of the carousel **22**. The carousel **22** includes one or more stations **400** for loading one or more consumables **18**. For example, as illustrated in FIG. **22**, a first station **400**A is loaded with a drill bit **18**A. A second station **400**B and a third station **400**C are each loaded with a resin cartridge **18**B. A fourth station **400**D and a fifth station **400**E are each loaded with a bolt **18**C. A sixth station **400**F is loaded with an adaptor **18**D. The currently selected station **400** of the carousel **22** may be determined by the intrinsically safe position detector **50**. An angular position of the carousel **22** may be identified by the rotary encoder **50**) based on a magnet, a target, or some other object mounted to the carousel **22**. For example, as illustrated in FIG. **22**, the carousel is positioned at 0°.
[0189] The drill rig **10** further includes an intrinsically safe control panel **420**. The control panel **420** is part of the user interface **304** and is connected to the controller **40**. FIGS. **23** and **24** illustrates a first example embodiment of a control panel **420**A and a second example embodiment of a control panel **420**B for controlling the drill rig **10**. The first control panel **420**A and the second control panel **420**B include a display screen **424**, a speaker **428**, and one or more buttons (e.g., a plurality of buttons). The one or more buttons are provided as a keypad **430**. The keypad **430** has a thickness between 0.15 millimeter (mm) and 1 mm. The one or more buttons include a combination of single press on/off buttons that toggle states when pressed and proportional input buttons that provide a signal to the controller proportional to the force applied on the button. When the one or more buttons includes a proportional input button, a force sensing resistor material is provided below the plastic overlay for each proportional input button. The force applied on the one or more buttons is transmitted to the force-sensing resistor material, which causes a drop in the electrical resistance of the force-sensing resistor. This drop in electrical resistance is detected to determine the amount of force applied to the one or more buttons. Since the one or more buttons use a resistive technology rather than capacitive touch technology, contact with human skin is not required to activate the one or more buttons. The one or more buttons can be activated even when a person is wearing gloves as is required for an operator in the mining environment.
[0190] Electrical detection signals from the one or more buttons are detected and a corresponding signal is provided to the controller **40**. The controller **40** then performs the functions assigned to one or more buttons based on the received signal. The one or more buttons include, for example, a stop button **432**, an isolator button **436**, one or more navigational buttons **440**, a home and/or select button **444**, and/or one or more control button banks **456**A-F. The first control panel **420**A includes a bolting light emitting diode (LED) **448** (e.g., a first LED) and a drilling LED **452** (e.g., a second LED). The second control panel **420**B includes a three-color LED **460**. In some embodiments, such as the embodiment illustrated in FIG. **23**, the one or more buttons include a text label describing the function of the button. In other embodiments, such as the embodiment illustrated in FIG. **24**, the one or more buttons include an icon corresponding to the function of the button. The stop button **432** allows a user to stop an operation of the drill rig **10**. When the stop button **432** is pressed, the controller **40** ceases all mechanical functions of the drill rig **10**. The one or more navigational buttons **440** and the home and/or select button **444** allow a user to navigate through options on the display **424**. The bolting LED **448** and the drilling LED **452** are each, for example, multicolor LEDs provide a status indication of the bolting operation (e.g., a first operation) and the drilling operation (e.g., a second operation) respectively.
[0191] The one or more control button banks **456**A-F each include one or more control buttons for

manually controlling an operation of the drill rig **10**. For example, as illustrated by FIG. **23**, a first control button bank **456**A includes control buttons for controlling the drill head **34** and a timber jack. The first control button bank **456**A includes a clockwise rotation button, a counterclockwise rotation button, a feed up button, and a feed down button. When the controller **40** determines that the clockwise rotation button is being pressed (that is, the controller **40** receives an input to rotate the drill head **34** in a clockwise direction), the controller **40** controls an actuator (e.g., a motor) of the drill head **34** to rotate the drill head **34** in a clockwise direction. When the controller **40** determines that the counterclockwise rotation button is being pressed (that is, the controller **40** receives an input to rotate the drill head **34** in a counterclockwise direction), the controller **40** controls an actuator of the drill head **34** to rotate the drill head **34** in a counterclockwise direction. When the controller **40** determines that the feed up button is being pressed (that is, the controller **40** receives an input to move the drill head **34** upward), the controller **40** controls an actuator of the drill head **34** to move the drill head **34** upward toward the roof. When the controller **40** determines that the feed up button is being pressed (that is, the controller **40** receives an input to move the drill head **34** downward), the controller **40** controls an actuator of the drill head **34** to move the drill head **34** downward away from the roof. The first control button bank **456**A also includes a timber jack up and timber jack down buttons that similarly control the timber jack to move up (e.g., to support the roof) and down (e.g., after the bolting operation). In some embodiments, the buttons provided in the first control button bank **456**A are proportional input buttons such that the force on the buttons dictates the speed of the corresponding operation.

[0192] A second control button bank **456**B includes control buttons for controlling a position of the carousel **22**, the loading arm **30**, and the carrier arm **130**. The second control button bank **456**B includes a carousel clockwise rotation button, a carousel counterclockwise rotation button, an arm to feed button, an arm from feed button, a washer loader up button, and a washer loader down button. When the controller **40** determines that the carousel clockwise rotation button is being pressed (that is, the controller **40** receives an input to rotate the carousel **22** in a clockwise direction), the controller **40** controls the actuator **46** to rotate the carousel in a clockwise direction. When the controller **40** determines that the carousel counterclockwise rotation button is being pressed (that is, the controller **40** receives an input to rotate the carousel **22** in a counterclockwise direction), the controller **40** controls the actuator **46** to rotate the carousel in a counterclockwise direction. When the controller **40** determines that the arm to feed button is being pressed (that is, the controller **40** receives an input to move the loading arm **30** to the carousel **22**), the controller **40** controls the second actuator **206** to move the loading arm **30** to the carousel **22**. When the controller **40** determines that the arm from feed button is being pressed (that is, the controller **40** receives an input to move the loading arm **30** away from the carousel **22**), the controller **40** controls the second actuator **206** to move the loading arm **30** away from the carousel **22**. When the controller **40** determines that the washer loader up button is being pressed (that is, the controller **40** receives an input to raise the carrier arm **130**), the controller **40** controls the actuator **136** to raise the carrier arm **130**. When the controller **40** determines that the washer loader down button is being pressed (that is, the controller **40** receives an input to lower the carrier arm **130**), the controller **40** controls the actuator **130** to lower the carrier arm **130**. In some embodiments, the buttons provided in the second control button bank **456**B are proportional input buttons such that the force on the buttons dictates the speed of the corresponding operation.

[0193] A third control button bank **456**C includes control buttons for opening/closing an arm gripper. When the controller **40** determines that the arm gripper open button is pressed (that is, the controller receives an input to open the clamps **222**), the controller **40** controls the clamp actuators to open the clamps **222**. When the controller **40** determines that the arm gripper close button is pressed (that is, the controller receives an input to close the clamps **222**), the controller **40** controls the clamp actuators to close the clamps **222**.

[0194] A fourth control button bank **456**D includes a bolt button for beginning a bolting operation

(see, e.g., FIG. **31**), and a resin button for beginning a resin injection operation (see, e.g., FIG. **30**). A fifth control button bank **456**E includes control buttons for selecting an automation state of the drill rig **10**. The fifth control button bank **456**E includes a semi/full auto button for selecting a semi/full automation mode of the drill rig **10** (see, e.g., FIG. **28**) and a pause/resume auto button for pausing or resuming an automatic operation of the drill rig **10**. A sixth control button bank **456**F includes buttons for controlling a drill operation of the drill rig **10**. The sixth control button bank **456**F includes a drill button for beginning a drill operation (see, e.g., FIG. **29**), plus (+) and minus (−) buttons to control the intensity or speed of the drilling operation, a water button to control a cooling water flow for the drilling operation, and a boost button to provide a power boost for the drilling operation. In some embodiments, the buttons provided in the sixth control button bank **456**F are proportional input buttons such that the force on the buttons dictates the speed of the corresponding operation.

[0195] The various control buttons of the control button banks **456**A-F provide controls for activating, deactivating, pausing, or resuming an automatic operation of the drill rig **10**. The various control buttons of the control button banks **456**A-F also provide controls for a manual control operation of the drill rig **10**. For example, in response to an error detected during an automatic operation of the drill rig **10**, the drill rig **10** may require an operator to manually control the drill rig **10** as a failsafe.

[0196] In some embodiments, various landmarks may be provided between the different button banks **456**A-F and around the one or more buttons so that the user can easily locate the button banks **456**A-F based on touch. In a mining environment, there may not always be sufficient light for an operator to easily make out the different buttons. FIG. **23**A illustrates one example of the landmarks provided on the control panel **420**A. A first landmark **460** is provided between the first control button bank **456**A and the second control button bank **456**B. The first landmark **460** may be an engraved landmark or a raised landmark such that a user may feel the first landmark **460** as the user moves their hand from the first control button bank **456**A to the second control button bank **456**B. An engraved landmark is a feature that is depressed into the surface membrane keypad and a raised landmark is a feature that is raised above a surface of the membrane keypad. A second set of landmarks **464** are provided around a first button **468** and a second button **472** of the first control button bank **456**A. In the example illustrated, the second set of landmarks **464** are directional landmarks indicating upwards and downwards around the first button **468** and the second button **472** respectively. The second set of landmarks **464** may include engraved landmarks or raised landmarks such that the user may feel the second set of landmarks **464** as the user moves their hand over the second set of landmarks **464**. The first button **468** is a feed up button that is used to move a component upwards and the second button **472** is a feed down button that is used to move a component downwards. The second set of landmarks **464** therefore indicate to a user that the first button **468** and second button **472** are upward and downward movement buttons of the respective button bank **456**A-F. A third landmark **476** is provided around a third button **480**. The third landmark **476** is also a directional landmark indicating an upward direction, however, the third landmark **476** is not provided as a set. Accordingly, the third landmark **476** is provided to indicate that the corresponding button **480** is a rotational button. In the example illustrated, the third button **480** is a clockwise rotation button and a fourth button **484** is provided below the third button **480**. The fourth button **484** is a counterclockwise rotation button. In some embodiments, a fourth set of landmarks may also be provided around buttons that are used for lateral movement. The fourth set of landmarks are directional landmarks indicating a left and right directions on the control panel **420**A. In some embodiments, one or more of the control button banks **456**A-F also include a bounding box **488** to visually differentiate between the different buttons. Bounding boxes are also provided around each of the one or more buttons. In some embodiments, the intrinsically safe control panel **420** further includes a connector that allows a connection of a second intrinsically safe control panel. The second intrinsically safe control panel **420** may be configured to control the

drill rig **10** from a distance (for example, remotely or from a remote location). The connector may be a wireless connector or a wired connector. In embodiments wherein the connector is a wireless connector, the wireless connector may be a Wi-Fi connector, a Bluetooth connector, a satellite connector, a cellular network connector, a radio transceiver, a combination thereof, or the like.
[0197] The display **424** is used to display a graphical user interface, such as the function interface **500** illustrated in FIGS. **25**-**27**B. FIG. **25** illustrates a drilling function interface **500**A. The drilling function interface **500**A includes a drill view tab **502**, a resin view tab **504**, and a bolt view tab **506**. The drilling function interface **500**A further includes a previous auto state indicator **508** for indicating a previous automated task performed by the drill rig **10** while in as fully automatic mode, a current auto state indicator **510** for indicating a current automated task performed by the drill rig **10** while in as fully automatic mode, and a next auto state indicator **512** for indicating a next automated task performed by the drill rig **10** while in as fully automatic mode. The drilling function interface **500**A also include an instrument panel **514** and a status panel **538***a*.
[0198] The instrument panel **514** displays a feed pressure gauge **516** and a feed pressure target indicator **518**, a rotational pressure gauge **520** and a rotational pressure target indicator **522**, an orientation index **524** including a north/south degree value **526** and an east/west degree value **528**, a timber jack pressure gauge **530**, a water flow rate gauge **532**, and a water pressure gauge **534** including a selector button **536**.
[0199] The status panel **538**A displays information relating to an automated drilling function, such as a target hole depth value **540**, a current hole depth indicator **542**, a feed speed indicator **544**, a rotation direction indicator **546**, a timber jack indicator **548**, a carousel position indicator **550**, a drill steel indicator **552**, a washer loader indicator **554**, a washer loader working position indicator **556**, and washer loader home position indicator **558**, and a top jaw reflex indicator **560**.
[0200] FIG. **26**A illustrates a resin function interface **500**B at a first time during an automated resin function. The resin function interface includes similar tabs and panels as the drill function interface **500**A. The resin function interface **500**B further includes a status panel **538**B. The status panel **538**B displays information relating to the automated resin function, such as a resin inserter indicator **562**, a resin indicator **564**, a carousel index degree indicator **566**, a loader arm indicator **568**, a mid-jaw indicator **570**, and a top-jaw indicator **572**. FIG. **26**B illustrates the resin function interface **500**B at a second time later than the first time during the automated resin function. The resin function interface **500**B remains mostly unchanged, with the exception of the resin indicator **564** and loader arm indicator **568** being shown in different positions on the status panel **538**B. This indicates that the automated resin operation was successful.
[0201] FIG. **27**A illustrates a bolting function interface **500**C at a first time during an automated bolting function. The bolting function interface **500**C includes similar tabs and panels as the drill function interface **500**A. The bolting function interface **500**C also includes a status panel **538**C. The status panel **538**C displays information relating to the automated resin function, such as a drill steel pot indicator **574**, a resin pot indicator **576**, a bolt pot indicator **578**, a dolly pot indicator **580**, and a bolt indicator **582**. FIG. **27**B illustrates the bolting function interface **500**C at a second time later than the first time during the automated bolting function. The bolting function interface **500**C remains mostly unchanged, with the exception of the bolt indicator **564** and loader arm indicator **568** being shown in different positions on the status panel **538**C. This indicates that the automated bolting operation was successful.
[0202] FIG. **28** is a flowchart illustrating an example method **600** for fully automated operation of the drill rig **10**. In the example illustrated, the method **600** includes receiving, at the controller **40**, a full automation mode request (at block **606**). For example, a user or operator of the drill rig **10** may press the full/semi auto button from the button bank **456**F. In some embodiments, the request may be received from the central controller **312**. The method **600** includes automatically performing a calibration operation of calibrating one or more sensors of the drill rig **10** (at block **608**). For example, the sensors may be the sensors **324** of FIG. **19**. The calibration operation may include

calibrating feed pressure of the actuators used for actuating various features of the drill rig **10**. The calibration operation may also include rotation pressure calibration. In some embodiments, the calibration operation may not be performed for every instance of the method **600**. The calibration operation may be performed at regular intervals, for example, after every tenth operation of the drill rig **10**. The method **600** also includes automatically performing a drilling operation (at block **610**) in response to receiving the full automation request. The drilling operation may include controlling the drill rig **10** to drill a hole into a surface of a working area **294**. The drilling operation is described further with respect to FIG. **29**. The method **600** further includes automatically performing a resin injection operation (at block **612**) subsequent to the drilling operation. For example, the resin injection operation may include injecting resin into the hole drilled into a surface of the working area **294**. The resin injection operation is described further with respect to FIG. **30**. The method **600** also includes automatically performing a bolting operation (at block **614**) subsequent to the resin injection operation. For example, the bolting operation may include inserting a bolt into the hole drilled into a surface of the working area **294**. The bolting operation is described further with respect to FIG. **31**. Following the bolting operation, the drill rig **10** may enter a stand-by mode until the drill rig **10** is moved to the next bolting location. While performing any of the blocks **608**-**614**, if the drill rig **10** encounters an error, the drill rig **10** may exit full automation mode and instruct a user to manually perform the next step. This process is detailed further in FIG. **32**.

[0203] FIG. **29** is a flowchart illustrating an example method **800** for automatically performing a drilling operation. The blocks described in method **800** may be performed in a different order than described herein. The method **800** begins when the drill rig **10** receives a control signal to begin an automatic drilling operation (e.g., at block **610** of FIG. **28**). In the example illustrated, the method **800** includes rotating, using the actuator **46**, the carousel **22** to a drill loading position (at block **802**). The drill loading position is a position in which the drill bit **18**A is aligned with the loading arm **30** (for example, as shown in FIG. **16**B). The controller **40** controls the actuator **46** to rotate the carousel **22** such that the drill bit **18**A is in the loading position based on the rotary position signals received from the encoder **50**. Specifically, the controller **40** continues to rotate the carousel **22** using the actuator **46** until the encoder **50** indicates that the carousel is in the drill loading position. The method **800** also includes securing the drill bit **18**A from the carousel **22** to the loading arm **30** for loading the drill bit **18**A to the drill head **34** (at block **804**). The controller **40** controls the clamp actuators to close the clamps **222** around the drill bit **18**A as shown in FIG. **16**D. The controller **40** determines that the drill bit **18**A is aligned with the loading arm **30** such that the clamps **222** can grasp the drill bit **18**A based on the signals received from the sensor **230**.

[0204] The method **800** also includes loading, using the washer loader assembly **110**, the washer **114** on the drill bit **18**A (at block **806**). The controller **40** controls the washer loader assembly **110** as discussed with respect to FIGS. **9**-**12** to load the washer **114** on the drill bit **18**A. The controller **40** controls the actuator **138** to place the carrier arm **130** on the stack of washers **122** as shown in FIGS. **16**B and **16**C. The magnet **182** under the carrier arm **130** secures a single washer **114**. Once the washer **114** is secured to the carrier arm **130**, the controller **40** controls the actuator **138** to raise the carrier arm **130** with the washer **114**. The controller **40** aligns the loading arm **30** with the carrier arm **130** such that when the loading arm **30** is raised the drill bit **18**A passes through an opening of the washer **114** and the carrier arm **130** as shown in FIGS. **16**D and **16**E. The controller **40** controls the first actuator **206** to raise the loading arm **30** such that the drill bit **18**A passes through the opening of the washer **114**.

[0205] The method **800** includes loading, using the loading arm **30**, the drill bit **18**A in the drill head **34** (at block **808**). The controller **40** controls the second actuator **210** to rotate the loading arm such that drill bit **18**A is above the drill head **34**. The controller **40** then controls the first actuator **206** to lower the drill bit **18**A into the drill head **34**. In some embodiments, rather than lowering the loading arm **30**, the drill head **34** may be raised to receive the drill bit **18**A. That drill head **34** may

include a chuck that is controlled by the controller **40** to secure the drill bit **18**A to the drill head **34**. Once the drill bit **18**A is loaded into the drill head **34**, the controller **40** rotates the loading arm away from the drill head **34** using the second actuator **206**. At the same time as being loaded into the drill head **34**, the drill bit **18**A is also loaded into the top plate **198**. The top plate **198** is axially aligned with the drill head **34** such that the drill bit **18**A is received in the drill head **34** and the top plate **198** at the same time. When the loading arm **30** is moved away from the drill head **34**, the washer **114** slides down the drill bit **18**A and settles on the top plate **198**.

[0206] The method **800** includes drilling, using the drill head **34**, the drill bit **18**A into the working surface **294** to create a drill hole (at block **810**). The controller **40** translates the drill head **34** and the top plate such that the top plate **198** and the washer **114** are in contact with the working surface **294** as shown in FIG. **161**. The controller **40** operates the drill head **34** to drill a hole in the working surface **294** using the drill bit **18**A as shown in FIG. **16**J.

[0207] The method **800** also includes securing the drill bit **18**A from the drill head **34** to the loading arm **30** for unloading the drill bit **18**A (at block **812**). The controller **40** retracts the drill head **34** to a home position after drilling. The controller **40** controls the second actuator **210** to move the loading arm **30** to the drill head **34** and controls the clamp actuator **225** to close the clamps **222** around the drill bit **18**A. The drill head **34** is disconnected from the drill bit **18**A, for example, by rotating a chuck of the drill head **34**. The method **800** further includes unloading, using the loading arm **30**, the drill bit **18**A to the carousel **22** (at block **814**). The controller **40** controls the second actuator to move the loading arm **30** from the drill head **34** to the carousel **22**. The controller **40** controls the clamp actuator **225** to open the clamps **222** such that drill bit **18**A is placed back in the carousel **22** as shown in FIG. **160**. The drill rig **10** may wait for a control signal to proceed to the next automatic operation (for example, the automatic resin injection operation or the automatic bolting operation). While performing any of BLOCKS **802**-**814**, if the drill rig **10** encounters an error, the drill rig **10** may exit full automation mode and instruct a user to manually perform the next step. This process is detailed further in FIG. **32**.

[0208] FIG. **30** is a flowchart illustrating an example method **900** for performing an automatic resin injection operation. The blocks described in method **900** may be performed in a different order than described herein. The method **900** begins when the drill rig **10** receives a control signal to begin an automatic resin injection operation (e.g., at block **612** of FIG. **28**). In the example illustrated, the method **900** includes rotating, using the actuator **46**, the carousel **22** to the resin cartridge loading position (at block **902**). The resin cartridge loading position is a position in which the resin cartridge **18**B is aligned with the loading arm **30** (for example, as shown in FIG. **17**A). The controller **40** controls the actuator **46** to rotate the carousel **22** such that the resin cartridge **18**B is in the loading position based on the rotary position signals received from the encoder **50**. Specifically, the controller **40** continues to rotate the carousel **22** using the actuator **46** until the encoder **50** indicates that the carousel is in the resin cartridge loading position. The method **900** also includes securing the resin cartridge **18**B from the carousel **22** to the loading arm **30** for loading the resin cartridge **18**B to the drill head **34** (at block **904**). The controller **40** controls the clamp actuators to close the clamps **222** around the resin cartridge **18**B. The controller **40** determines that the resin cartridge **18**B is aligned with the loading arm **30** such that the clamps **222** can grasp the resin cartridge **18**B based on the signals received from the sensor **230**.

[0209] The method **900** includes loading, using the loading arm **30**, the resin cartridge **18**B in the drill head **34** (at block **906**). The controller **40** controls the second actuator **210** to rotate the loading arm such that resin cartridge **18**B is above the drill head **34**. The controller **40** then controls the first actuator **206** to lower the resin cartridge **18**B into the drill head **34**. In some embodiments, rather than lowering the loading arm **30**, the drill head **34** may be raised to receive the resin cartridge **18**B. Once the resin cartridge **18**B is loaded into the drill head **34**, the controller **40** rotates the loading arm **30** away from the drill head **34** using the second actuator **206**.

[0210] The method **900** includes injecting, using the resin cartridge **18**B, resin into the hole drilled

in the working surface **294** (at block **908**). The controller **40** translates the drill head **34** such that a resin opening of the resin cartridge **18**B is inserted into the top plate **198** as shown in FIG. **17**E. The controller **40** operates the drill head **34** to activate the resin cartridge **18**B and to inject the resin in the hole drilled in the working surface **294**.

[0211] The method **900** also includes securing the resin cartridge **18**B from the drill head to the loading arm **30** for unloading the resin cartridge **18**B (at block **910**). The controller **40** retracts the drill head **34** to a home position after resin injection. The controller **40** controls the second actuator **210** to move the loading arm **30** to the drill head **34** and controls the clamp actuator **225** to close the clamps **222** around the spent resin cartridge **18**B. The method **900** further includes unloading, using the loading arm **30**, the spent resin cartridge **18**B to the carousel **22** (at block **912**). The controller **40** controls the second actuator **210** to move the loading arm **30** from the drill head **34** to the carousel **22**. The controller **40** controls the clamp actuator **225** to open the clamps **222** such that resin cartridge **18**B is placed back in the carousel **22** as shown in FIG. **17**H. In some embodiments, the loading arm **30** may unload the spent resin cartridge **18**B to a different location. The resin injection operation then ends. The drill rig **10** may wait for a control signal to proceed to the next automatic operation (for example, the automatic bolting operation). While performing any of BLOCKS **902-912**, if the drill rig **10** encounters an error, the drill rig **10** may exit full automation mode and instruct a user to manually perform the next step. This process is detailed further in FIG. **32**.

[0212] FIG. **31** is a flowchart illustrating an example method **1000** for performing an automatic bolting operation. The blocks described in method **100** may be performed in a different order than described herein. The method **1000** includes rotating, using the actuator **46**, the carousel **22** to a bolt loading position (at block **1002**). The bolt loading position is a position in which the bolt **18**C is aligned with the loading arm **30** (for example, as shown in FIG. **18**A). The controller **40** controls the actuator **46** to rotate the carousel **22** such that the bolt **18**C is in the loading position based on the rotary position signals received from the encoder **50**. Specifically, the controller **40** continues to rotate the carousel **22** using the actuator **46** until the encoder **50** indicates that the carousel **22** is in the bolt loading position. The method **1000** also includes securing the bolt **18**C from the carousel **22** to the loading arm **30** for loading the bolt **18**C to the drill head **34** (at block **1004**). The controller **40** controls the clamp actuators to close the clamps **222** around the bolt **18**C. The controller **40** determines that the bolt **18**C is aligned with the loading arm **30** such that the clamps **222** can grasp the bolt **18**C based on the signals received from the sensor **230**.

[0213] The method **1000** includes loading, using the loading arm **30**, the bolt **18**C in the drill head **34** (at block **1006**). The controller **40** controls the second actuator **210** to rotate the loading arm such that bolt **18**C is above the drill head **34**. The controller **40** then controls the first actuator **206** to lower the bolt **18**C into the drill head **34**. In some embodiments, rather than lowering the loading arm **30**, the drill head **34** may be raised to receive the bolt **18**C. Once the bolt **18**C is loaded into the drill head **34**, the controller **40** rotates the loading arm **30** away from the drill head **34** using the second actuator **206**.

[0214] The method **1000** includes aligning, using the drill head **34**, the bolt **18**C with the drill hole in the working surface **294** (at block **1008**). The controller **40** raises the drill head **34** such that the bolt **18**C is received in the top plate **198** and aligned with the drill hole in the working surface **294**. The top plate **198** secures the bolt **18**C such that the bolt **18**C can be dismounted from the drill head **34**. Once the bolt **18**C is secured by the top plate, the controller **40** lowers the drill head **34** away from the bolt **18**C to the home position. The method **100** includes rotating, using the actuator **46**, the carousel **22** to an adapter loading position (at block **1010**). The adapter loading position is a position in which the adapter **18**D is aligned with the loading arm **30** (for example, as shown in FIG. **18**F). The controller **40** controls the actuator **46** to rotate the carousel **22** such that the adapter **18**D is in the loading position based on the rotary position signals received from the encoder **50**. Specifically, the controller **40** continues to rotate the carousel **22** using the actuator **46** until the

encoder **50** indicates that the carousel is in the adapter loading position. The method **1000** also includes securing the adapter **18**D from the carousel **22** to the loading arm **30** for loading the adapter **18**D to the drill head **34** (at block **1012**). The controller **40** controls the clamp actuators to close the clamps **222** around the adapter **18**D. The controller **40** determines that the adapter **18**D is aligned with the loading arm **30** such that the clamps **222** can grasp the adapter **18**D based on the signals received from the sensor **230**. In some embodiments, the blocks **1008**-**1012** may be performed simultaneously with blocks **1004** and **1006**.

[0215] The method **1000** includes loading, using the loading arm **30**, the adapter **18**D in the drill head **34** (at block **1014**). The controller **40** controls the second actuator **210** to rotate the loading arm such that adapter **18**D is above the drill head **34**. The controller **40** then controls the first actuator **206** to lower the adapter **18**D into the drill head **34**. In some embodiments, rather than lowering the loading arm **30**, the drill head **34** may be raised to receive the adapter **18**D. Once the adapter **18**D is loaded into the drill head **34**, the controller **40** rotates the loading arm **30** away from the drill head **34** using the second actuator **206**. The method **1000** further includes driving, using the drill head **34** and the adapter **18**D, the bolt **18**C into the working surface **294** (at block **1016**). The controller **40** controls the drill head **34** to couple the adapter **18**D to the bolt **18**C. Once the adapter **18**D is coupled to the bolt **18**C, the controller **40** controls the drill head **34** to insert the bolt **18**C into the drill hole in the working surface **294**. The bolt **18**C is held in place in the drill hole with the resin previously injected into the drill hole. The controller **40** lowers the drill head **34** to the home position.

[0216] The method **1000** also includes securing the adapter **18**D from the drill head **34** to the loading arm **30** for unloading the adapter **18**D (at block **1018**). The controller **40** controls the second actuator **210** to move the loading arm **30** to the drill head **34** and controls the clamp actuator **225** to close the clamps **222** around the adapter **18**D. The method **1000** further includes unloading, using the loading arm **30**, the adapter **18**D to the carousel **22** (at block **1020**). The controller **40** controls the second actuator **210** to move the loading arm **30** from the drill head **34** to the carousel **22**. The controller **40** controls the clamp actuator **225** to open the clamps **222** such that adapter **18**D is placed back in the carousel **22** as shown in FIG. **18**M. The automatic bolting operation then ends. The drill rig **10** may wait for a control signal to proceed to the next automatic operation (for example, restarting the full automation mode). While performing any of blocks **1004**-**1020**, if the drill rig **10** encounters an error, the drill rig **10** may exit full automation mode and instruct a user to manually perform the next step. This process is detailed further in FIG. **32**.

[0217] FIG. **32** is a flowchart illustrating an example method **1100** of performing an error-handling operation of the drill rig **10**. While performing any automatic operation (i.e., any of the blocks **608**-**614** of FIG. **28**, blocks **802**-**814** of FIG. **29**, blocks **902**-**912** of FIG. **30**, and blocks **1002**-**1020** of FIG. **31**), the drill rig **10** may encounter an error. The drill rig **10** may enter a failsafe operation mode to perform an error-handling operation in response to the error. The method **1100** includes performing any automatic operation of the drill rig **10** while in full automation mode (at block **1102**). The automatic operation may be any of the blocks **608**-**614** of FIG. **28**, blocks **802**-**814** of FIG. **29**, blocks **902**-**912** of FIG. **30**, and blocks **1002**-**1020** of FIG. **31**. The automatic operation may also be another operation not listed above. The method also includes determining, using the controller **40**, whether an error has occurred (at block **1104**) during one of the automatic operations (e.g., the automatic drilling operation, the automatic resin injection operation, and the automatic bolting operation). The error may be detected by the sensors **324** of the drill rig **10**, a length of time since the last step was performed, or by some other means. When no error is detected, the method **1100** returns to block **1102** (e.g., the drill rig **10** proceeds to the next automatic operation). In response to detecting the error, the method **1100** includes directing a user to manually perform an operation (at block **1106**). For example, the controller **40** displays an alert on the display **424** indicating that an error has occurred during operation. In some embodiments, the controller **40** may display the error status using the multi-color LEDs **448** and **452**. On the display **424**, the controller

**40** may provide an instruction for a user to manually complete the remaining operation, for example, using one of the display screens as shown in FIGS. **25**-**27**B.
[0218] The method **1100** include receiving, via the control panel **420**, user input corresponding to the operation (at block **1108**). As discussed above with respect to FIGS. **23**-**24**, the user may control the drill rig **10** using one or more buttons provided on the control panel **420**. Specifically, the user presses the one or more buttons to continue the present operation of the drill rig **10**. The method **100** also includes performing, using the controller **40**, the operation based on user input (at block **1110**). As discussed above, the controller **40** receives the user input from the control panel **420**. The controller **40** then controls the corresponding component based on the user input.
[0219] The method **1100** includes determining, using the controller **40**, whether the error is resolved (at block **1112**). The controller **40** may determine whether the error is resolved based on the sensors **324**. When the error is not resolved, the method **1100** returns to block **1108** to continue manual operation. When the error is resolved, the method **1100** includes generating, using the controller **40**, an alert indicating that the drill is ready for automated operation (at block **1114**). For example, the controller **40** displays an alert on the display **424** indicating that the error has been resolved. In some embodiments, the controller **40** may display the error status using the multi-color LEDs **448** and **452**.
[0220] The method **110** includes receiving, via the control panel **420**, an input to resume automated operation (at block **1116**). For example, the user may press the full automation button on the control panel **420**A. The method **1100** further includes resuming, using the controller **40**, automated operation of the drill rig (at block **1118**). The automated operation may include one of the drilling operation, the resin injection operation, and the bolting operation. The controller **40** may resume operation from a point where manual operation was stopped after detecting the error.
[0221] Therefore, embodiments described herein provide systems and methods for performing fully automatic operations of a drill rig, such as a bolter. Although aspects have been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects as described.

## Claims

**1**. A drill rig for an automatic bolter comprising: a carousel rotatable about an axis and configured to store a bolt and a second type of consumable; a drill head configured to apply the bolt and the second type of consumable to a working surface; a loading assembly including: a loading arm configured to move laterally between the carousel and the drill head, and clamps at one end of the loading arm configured to secure the bolt and the second type of consumable; and a controller in electronic communication with carousel, the drill head, and the loading assembly and configured to: receive a full automation mode request; automatically perform a drilling operation on the working surface in response to receiving the full automation mode request; automatically perform, using the second type of consumable, a second operation on the working surface subsequent to the drilling operation; and automatically perform, using the bolt, a bolting operation on the working surface subsequent to the second operation.
**2**. The drill rig of claim 1, wherein the second type of consumable is a resin cartridge.
**3**. The drill rig of claim 2, wherein the second operation is a resin injection operation.
**4**. The drill rig of claim 3, wherein to perform the second operation, the controller is further configured to: rotate, using a first actuator, the carousel to a resin cartridge loading position; secure the resin cartridge from the carousel to the loading arm; load, using the loading arm, the resin cartridge in the drill head; inject resin into the hole drilled in the working surface; secure the resin cartridge from the drill head to the loading arm; and unload, using the loading arm, the spent resin cartridge to the carousel.
**5**. The drill rig of claim 1, wherein the carousel is further configured to store a third type of

consumable.
**6**. The drill rig of claim 5, wherein the second type of consumable is a resin cartridge and the third type of consumable is a drill bit.
**7**. The drill rig of claim 5, wherein the third type of consumable is an adaptor; and wherein the controller is further configured to use the adaptor to automatically perform the bolting operation.
**8**. The drill rig of claim 1, wherein the second type of consumable is an extension drill rod; and wherein the controller is further configured to use the extension drill rod to automatically perform the drilling operation.
**9**. A method for operating a drill rig for an automatic bolter comprising, the method comprising: receiving a full automation mode request; automatically performing a drilling operation on a working surface in response to receiving the full automation mode request; automatically performing, using a carousel rotatable about an axis and configured to store a bolt and a second type of consumable, a second operation involving the second type of consumable on the working surface subsequent to the drilling operation; and automatically performing, using the bolt, a bolting operation on the working surface subsequent to the second operation.
**10**. The method of claim 9, wherein automatically performing the resin injection operation includes: rotating, using a first actuator, the carousel to a resin cartridge loading position; securing a resin cartridge from the carousel to a loading arm of the drill rig; loading, using the loading arm, the resin cartridge in a drill head of the drill rig; injecting resin into the hole drilled in the working surface; securing the resin cartridge from the drill head to the loading arm; and unloading, using the loading arm, the spent resin cartridge to the carousel.
**11**. The method of claim 9, wherein automatically performing the bolting operation includes using an adaptor stored in the carousel.
**12**. The method of claim 9, wherein automatically performing the drilling operation includes using an extension drill rod stored in the carousel.
**13**. A drill rig for an automatic bolter comprising: a carousel rotatable about an axis and configured to store a drill bit and a second type of consumable; a drill head configured to apply the drill bit and the second type of consumable to a working surface; a loading assembly including: a loading arm configured to move laterally between the carousel and the drill head, and clamps at one end of the loading arm configured to secure the drill bit and the second type of consumable; and a controller in electronic communication with the carousel, the drill head, and the loading assembly and configured to: receive a full automation mode request; automatically perform, using the drill bit, a drilling operation on the working surface in response to receiving the full automation mode request; automatically perform, using the second type of consumable, a second operation on the working surface subsequent to the drilling operation; and automatically perform a bolting operation on the working surface subsequent to the second operation.
**14**. The drill rig of claim 13, wherein the second type of consumable is a resin cartridge.
**15**. The drill rig of claim 14, wherein the second operation is a resin injection operation.
**16**. The drill rig of claim 15, wherein to perform the second operation, the controller is further configured to: rotate, using a first actuator, the carousel to a resin cartridge loading position; secure the resin cartridge from the carousel to the loading arm; load, using the loading arm, the resin cartridge in the drill head; inject resin into the hole drilled in the working surface; secure the resin cartridge from the drill head to the loading arm; and unload, using the loading arm, the spent resin cartridge to the carousel.
**17**. The drill rig of claim 13, wherein the carousel is further configured to store a third type of consumable.
**18**. The drill rig of claim 17, wherein the third type of consumable is an adaptor; and wherein the controller is further configured to use the adaptor to automatically perform the bolting operation.
**19**. The drill rig of claim 13, wherein the second type of consumable is an extension drill rod; and wherein the controller is further configured to use the extension drill rod to automatically perform

the drilling operation.

**20**. The drill rig of claim 13, wherein the second type of consumable is a combined bolt-and-resin type bolt.