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Systems and methods for downhole service tools

Abstract

A mechanical service tool that may include one or more anchors, a cutter, a communication and control system, and one or more sensors, as well as methods for operating the mechanical service tool, are provided. The one or more anchors may extend radially from the mechanical service tool and the cutter may move relative to the mechanical service tool. The cutter may include a drilling bit. The communication and control system may obtain remote commands that control the cutter, the one or more anchors, or both. The one or more sensors may detect operational conditions of the mechanical service tool and may be operatively coupled to the communication and control system.

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Background/Summary

CROSS REFERENCE PARAGRAPH (1) This application is a Continuation of U.S. application Ser. No. 16/649,478, filed Mar. 20, 2020, which is a National Stage Entry of PCT/US2018/052171, filed Sep. 21, 2018, which claims the benefit of U.S. Provisional Application No. 62/561,414, entitled “SYSTEMS AND METHODS FOR DOWNHOLE SERVICE TOOLS,” filed Sep. 21, 2017, the disclosure of which is are hereby incorporated herein by reference.

BACKGROUND
(1) This disclosure relates to systems and methods for performing mechanical operations within a wellbore and/or a casing using downhole mechanical service tools.
(2) This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present techniques, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as an admission of any kind.
(3) Producing hydrocarbons from a wellbore drilled into a geological formation is a remarkably complex endeavor. In many situations, a casing may be disposed within the wellbore to assist in transporting hydrocarbons from within the geological formation to a collection facility at the surface of the wellbore. In other situations, the casing may be used to isolate and/or protect delicate systems within the casing from physical damage (e.g., abrasion, exposure to corrosive wellbore fluids) due to contact with the geological formation. However, there may be times where it is desirable to gain access behind the casing in certain specific locations.

SUMMARY

(4) A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

(5) In one example, a mechanical service tool includes one or more anchors, a cutter, a communication and control system, and one or more sensors. The one or more anchors extend radially from the mechanical service tool. The cutter moves relative to the mechanical service tool and includes a drilling bit. The communication and control system obtains remote commands that control the cutter, the one or more anchors, or both. The one or more sensors detect operational conditions of the mechanical service tool and are operatively coupled to the communication and control system.

(6) In another example, a method includes disposing a mechanical service tool within a casing of a wellbore, fastening the mechanical service tool to an interior surface of the casing through one or more anchors, extending a cutter comprising a drilling bit from the mechanical service tool, and machining the interior surface of the casing using the cutter.

(7) In another example, an anchor of a mechanical service tool includes an actuator, a caliper, and a power unit. The caliper includes a friction pad that contacts an interior surface of a wellbore casing. The power unit extends the actuator from the anchor towards the interior surface of the casing.

(8) In another example, a method includes disposing a mechanical service tool within a casing of a wellbore, extending an actuator of an anchor of the mechanical service tool, and moving a caliper towards an interior surface of the casing using the actuator.

(9) In another example, an impact system of a mechanical service tool includes at least one shaft, an impact weight, a spring, a hammer mechanism, and a drilling bit. The at least one shaft is coupled to a driving motor. The impact weight is disposed within a housing of the mechanical service tool and the at least one shaft extends through an opening of the impact weight. The spring is coupled to the impact weight and the housing, and coils about an axis. The hammer mechanism engages or disengages the at least one shaft from the driving motor. The drilling bit is coupled to the at least one shaft of the mechanical service tool.

(10) In another example, a method includes rotating at least one shaft of an impact system using a driving motor and winding a spring about an axis. The at least one shaft is disposed within a central portion of the spring. The method additionally includes unwinding the spring about the axis and accelerating an impact weight of the impact system. Furthermore, the method includes decelerating the impact weight and imposing a force on a drilling bit.

(11) In another example, a jar tool of a mechanical service tool includes a threaded rod disposed within a tool body, a spring, and a hammer assembly. The threaded rod moves an anvil in a first direction to a first position within the jar tool. The spring applies a first force on the anvil in a second direction. The hammer assembly moves the anvil in the second direction towards a second position within the jar tool to generate a second force in the second direction that loosens the mechanical service tool from an obstruction within a casing.

(12) In another example, a method includes disposing a jar tool within a casing of a wellbore, moving an anvil of the jar tool to a first position in a first direction, tensioning a spring coupled to the anvil to apply a first force to the anvil in a second direction, and moving the anvil in the second direction towards a second position to generate a second force in the second direction that loosens the mechanical service tool from an obstruction within the casing.

(13) In another example, a patching tool of a mechanical service tool includes a threaded rod disposed within a patching sleeve, a shuttle coupled to the threaded rod, and a nose cone configured to guide the patching tool through a casing. The threaded rod couples to a driving motor that rotates the threaded rod. The shuttle couples to the threaded rod and moves axially along the threaded rod to expand the patching sleeve. The patching sleeve contacts an interior surface of the casing. The

nose cone has a chamfered interior edge that guides the patching tool through the casing and reduces a risk of the patching tool catching the patching sleeve after the patching sleeve has expanded.
(14) In another example, a method includes disposing a patching tool within a casing, rotating a threaded rod using a driving motor to move a shuttle, and expanding a patching sleeve within the casing when the threaded rod moves the shuttle from a first position to a second position.
(15) In another example, a rotary cutter tool of a mechanical service tool includes one or more centralizing arms, one or more cutting arms, a cutter coupled to each cutting arm, and control electronics. The one or more centralizing arms radially extend from the rotary cutter tool and contact an interior surface of a casing. The one or more cutting arms radially extend from the rotary cutter tool and machine the interior surface of the casing. The control electronics obtains remote commands to control the centralizing arms, the cutting arms, and/or the cutter.
(16) In another example, a method includes disposing a rotary cutter tool within a casing of a wellbore, centralizing the rotary cutter tool within the casing using one or more centralizing arms, extending one or more cutters from the rotary cutter tool towards an interior surface of the casing, and machining the interior surface of the casing using the one or more cutters.
(17) In another example, a flow control device of a mechanical service tool includes a stationary member including a first slot, a floating element disposed circumferentially inward of the stationary member, and a prime mover disposed circumferentially inward of the floating element. The stationary member contacts an interior surface of a casing. The floating element includes a second slot and rotates about a central axis. The prime mover is coupled to the mechanical service tool, the mechanical service tool rotates the prime mover about the central axis, and the prime mover rotates the floating element about the central axis.
(18) In another example, a method includes disposing a flow control device within a casing of a wellbore, anchoring a mechanical service tool to the casing, rotating a prime mover about a central axis using the mechanical service tool, rotating a floating element using the prime mover, and regulating a flow of fluid entering the casing.
(19) In another example, a mechanical charging tool of a mechanical service tool includes an input shaft, a generator, and one or more output leads. The input shaft is rotated by a motor unit of the mechanical service tool. The generator converts rotational energy of the input shaft to electrical energy. The one or more output leads transfer the electrical energy to one or more components of the mechanical service tool.
(20) In another example, a method includes disposing a mechanical charging tool within a casing of a wellbore; rotating an input shaft of the mechanical charging tool using a mechanical service tool, rotating a generator using the input shaft, generating electrical energy using the generator, and transmitting the electrical energy to the mechanical service tool using one or more leads of the mechanical charging tool.
(21) Various refinements of the features noted above may be undertaken in relation to various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. The brief summary presented above is intended to familiarize the reader with certain aspects and contexts of embodiments of the present disclosure without limitation to the claimed subject matter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings in which:

(2) FIG. **1** is a schematic diagram of a wellbore logging system and cable that may obtain data measurements and move a mechanical service tool along a length of the wellbore, in accordance with an embodiment of the present disclosure;

(3) FIG. **2** is a perspective view of the mechanical service tool of FIG. **1**, which illustrates subcomponents of the mechanical service tool, in accordance with an embodiment of the present disclosure;

(4) FIG. **3** is a method of operating the mechanical service tool of FIG. **2**, in accordance with an embodiment of the present disclosure;

(5) FIG. **4** is a perspective view of the mechanical service tool of FIG. **2**, which illustrates anchors coupled to the mechanical service tool, in accordance with an embodiment of the present disclosure;

(6) FIG. **5** is a perspective view of the mechanical service tool of FIG. **2**, which illustrates a cutter mechanism coupled to the mechanical service tool, in accordance with an embodiment of the present disclosure;

(7) FIG. **6** is a perspective view of the mechanical service tool of FIG. **2**, which illustrates the cutter mechanism generating an axial cut within a casing, in accordance with an embodiment of the present disclosure;

(8) FIG. **7** is a perspective view of the mechanical service tool of FIG. **2**, which illustrates the cutter mechanism generating a radial cut within the casing, in accordance with an embodiment of the present disclosure;

(9) FIG. **8** is a cross-sectional view of the cutter mechanism of FIG. **5**, which illustrates the cutter mechanism in a retracted position within the mechanical service tool, in accordance with an embodiment of the present disclosure;

(10) FIG. **9** is a cross-sectional view of the cutter mechanism of FIG. **5**, which illustrates the cutter mechanism in an extended position from the mechanical service tool, in accordance with an embodiment of the present disclosure;

(11) FIG. **10** is a cross-sectional view of the cutter mechanism of FIG. **5**, which illustrates the cutter mechanism in generating the radial cut, in accordance with an embodiment of the present disclosure;

(12) FIG. **11** is a perspective view of the mechanical service tool of FIG. **2**, which illustrates sensors disposed about the mechanical service tool, in accordance with an embodiment of the present disclosure;

(13) FIG. **12** is a method of operating the anchors of FIG. **4**, in accordance with an embodiment of the present disclosure;

(14) FIG. **13** is a perspective view of the mechanical service tool of FIG. **2**, which illustrates the anchors of the mechanical service tool, in accordance with an embodiment of the present disclosure;

(15) FIG. **14** is a close-up perspective view of the anchors of FIG. **13**, in accordance with an embodiment of the present disclosure;

(16) FIG. **15** is a perspective view of an impact system that may couple to the mechanical service tool of FIG. **2**, in accordance with an embodiment of the present disclosure;

(17) FIG. **16** is a method of operating the impact system of FIG. **15**, in accordance with an embodiment of the present disclosure;

(18) FIG. **17** is a perspective view of the impact system of FIG. **15**, showing an impact weight moving to an initial position, in accordance with an embodiment of the present disclosure;

(19) FIG. **18** is a perspective view of the impact system of FIG. **15**, showing the impact weight

moving to a resting position and generating an impact force, in accordance with an embodiment of the present disclosure;
(20) FIG. **19** is a perspective view of a jar tool that may couple to the mechanical service tool of FIG. **2**, in accordance with an embodiment of the present disclosure;
(21) FIG. **20** is a method of operating the jar tool of FIG. **19**, in accordance with an embodiment of the present disclosure;
(22) FIG. **21** is a perspective view of a hammer assembly of the jar tool of FIG. **19**, illustrating the hammer assembly in an engaged position, in accordance with an embodiment of the present disclosure;
(23) FIG. **22** is a perspective view of the hammer assembly FIG. **21**, illustrating the hammer assembly in a released position, in accordance with an embodiment of the present disclosure;
(24) FIG. **23** is a perspective view of a patching tool that may couple to the mechanical service tool of FIG. **2**, in accordance with an embodiment of the present disclosure;
(25) FIG. **24** is a method of operating the patching tool of FIG. **23**, in accordance with an embodiment of the present disclosure;
(26) FIG. **25** is a perspective view of the patching tool of FIG. **23**, illustrating the patching tool expanding a patching sleeve, in accordance with an embodiment of the present disclosure;
(27) FIG. **26** is a perspective view of a rotary cutter tool that may traverse the wellbore of FIG. **1**, in accordance with an embodiment of the present disclosure;
(28) FIG. **27** is a method of operating the rotary cutter tool of FIG. **26**, in accordance with an embodiment of the present disclosure;
(29) FIG. **28** is a perspective view of the rotary cutter tool of FIG. **26**, illustrating the rotary cutter tool making a cut within a portion of the casing, in accordance with an embodiment of the present disclosure;
(30) FIG. **29** is a cross-sectional view of a flow control device that may regulate the flow of fluids within the wellbore of FIG. **1**, in accordance with an embodiment of the present disclosure;
(31) FIG. **30** is a method of operating the flow control device of FIG. **29**, in accordance with an embodiment of the present disclosure;
(32) FIG. **31** is a perspective view of the flow control device of FIG. **29**, illustrating a floating element and a threaded prime mover disposed within the flow control device, in accordance with an embodiment of the present disclosure;
(33) FIG. **32** is a perspective view of the flow control device of FIG. **29**, illustrating a threaded floating element disposed within the flow control device, in accordance with an embodiment of the present disclosure;
(34) FIG. **33** is a perspective view of the flow control device of FIG. **29**, illustrating a threaded and notched floating element disposed within the flow control device, in accordance with an embodiment of the present disclosure;
(35) FIG. **34** is a perspective view of a mechanical charging tool that may couple to the mechanical service tool of FIG. **1**, in accordance with an embodiment of the present disclosure;
(36) FIG. **35** is a method of operating the mechanical charging tool of FIG. **34**, in accordance with an embodiment of the present disclosure.
DETAILED DESCRIPTION
(37) One or more specific embodiments of the present disclosure will be described below. These described embodiments are only examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might

be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

(38) When introducing elements of various embodiments of the present disclosure, the articles “a,” “an,” and “the” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to “one embodiment” or “an embodiment” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

(39) With this in mind, FIG. **1** illustrates a well-logging system **10** that may employ the systems and methods of this disclosure. The well-logging system **10** may be used to convey a downhole tool (e.g., a mechanical service tool **12**) or a dummy weight through a geological formation **14** via a wellbore **16**. The mechanical service tool **12** may be conveyed on a cable **18** via a logging winch system **20**. Although the logging winch system **20** is schematically shown in FIG. **1** as a mobile logging winch system carried by a truck, the logging winch system **20** may be substantially fixed (e.g., a long-term installation that is substantially permanent or modular). Any suitable cable **18** for well logging may be used. The cable **18** may be spooled and unspooled on a drum **22** and an auxiliary power source **24** may provide energy to the logging winch system **20** and/or the mechanical service tool **12**.

(40) The mechanical service tool **12** may perform various mechanical operations (e.g., machining operations) within the wellbore **16** and/or may provide logging measurements **26** to a data processing system **28** via any suitable telemetry (e.g., via electrical or optical signals pulsed through the geological formation **14** or via mud pulse telemetry). The data processing system **28** may process the logging measurements. The logging measurements **26** may include certain properties of the mechanical service tool **12** (e.g., location, orientation) that may indicate the operational status of the mechanical service tool **12**.

(41) To this end, the data processing system **28** thus may be any electronic data processing system that can be used to carry out the systems and methods of this disclosure. For example, the data processing system **28** may include a processor **30**, which may execute instructions stored in memory **32** and/or storage **34**. As such, the memory **32** and/or the storage **34** of the data processing system **28** may be any suitable article of manufacture that can store the instructions. The memory **32** and/or the storage **34** may be ROM memory, random-access memory (RAM), flash memory, an optical storage medium, or a hard disk drive, to name a few examples. A display **36**, which may be any suitable electronic display, may provide a visualization, a well log, or other indication of properties in the geological formation **14** or the wellbore **16** using the logging measurements **26**.

(42) The mechanical service tool **12** may be used to perform a variety of downhole machining operations. Turning now to FIG. **2**, an embodiment of the mechanical service tool **12** is shown disposed within a casing **40** of the wellbore **16**. The casing **40** may serve to isolate an interior region **42** of the wellbore **16** from the geological formation **14**. In another embodiment, the mechanical service tool **12** may be disposed directly within the wellbore **16** without the casing **40**. As described in more detail herein, the mechanical service tool **12** may be used to perform various mechanical operations (e.g., milling, grinding, cutting) within the casing **40** and/or against the formation **14** along the wall of the wellbore **16**. With the foregoing in mind, it may be useful to first describe one embodiment of the mechanical service tool **12**. The mechanical service tool **12** may include a tool body **44**, which may couple to one or more anchors **46** and/or additional subcomponents. The mechanical service tool **12** may include an upper end portion **48** and a lower end portion **50**. A cutter mechanism **52** may be disposed between the upper end portion **48** and the lower end portion **50** of the mechanical service tool **12**. The cutter mechanism **52** may be used to perform the mechanical operations (e.g., machining, grinding, cutting) on the casing **40**. To facilitate further discussion, the mechanical service tool **12** and its subcomponents may be

described with reference to a longitudinal **54** axis or direction, and a radial **56** axis or direction.

(43) A method **60** may be used to operate the mechanical service tool **12** and/or carry out the mechanical operations set forth above, as shown in FIG. **3**. Block **62** relates to FIG. **2** discussed above, in which the mechanical service tool **12** may be raised or lowered into the wellbore **14** via the cable **18**. The machining operations may include various portions (e.g., individual machining processes), embodiments of which are shown in FIGS. **4-11**. The portions may be executed in a different order than presented in FIGS. **4-11**. Additionally or otherwise, the machining operations may include additional portions or fewer portions than those shown in FIGS. **4-11**.

(44) Block **64** of FIG. **3** relates to FIG. **4**. The anchors **46** may be used to restrict longitudinal **54** and/or radial **56** movement of the mechanical service tool **12** with respect to the casing **40**. The anchors **46** may include friction pads **66** that may extend radially **56** from the mechanical service tool **12** towards an interior surface **70** of the casing **40**. The friction pads **66** may apply a force **68** against the interior surface **70**. In one embodiment, the force **68** may be sufficient to support the weight of the mechanical service tool **12** and prevent the mechanical service tool **12** from sliding in the longitudinal **54** direction within the casing **40**. In another embodiment, the cable **18** may additionally support a portion or all of the weight of the mechanical service tool **12**. Additionally or otherwise, the anchors **46** may centralize the mechanical service tool **12** within the casing **40** by ensuring that an axial centerline **72** of the mechanical service tool **12** and an axial centerline **74** of the casing **40** are concentric.

(45) Block **78** of FIG. **3** relates to FIG. **5**. The cutter mechanism **52** may include linkages **80** which allow a cutting head **82** housing a drilling bit **84** to extend towards the interior surface **70** of the casing **40**. As such, the drilling bit **84** may extend perpendicular to the axial centerline **74** of the casing, or at an angle deviating from the axial centerline **74**. The drilling bit **84** may rotate through driving motor **85** (e.g., hydraulic motor, electric motor) to facilitate drilling (e.g., penetrating a material). The linkages **80** may couple to actuators (not shown), which may apply a force **86** to the drilling bit **84**, and hence the interior surface **70** of the casing **40**. As such, the drilling bit **84** may drill (e.g., penetrate) into the casing **40**. The drilling bit **84** may be substituted for an additional machining tool, such as an end mill, grinding wheel, or the like. Although only one drilling bit **84** is shown in the illustrated embodiment, the cutting head **82** may house 1, 2, 3, 4, or more drilling bits **84**.

(46) In one embodiment, reaction pads **88** (e.g., rollers) may radially extend towards the interior surface **70** of the casing **40** in addition to, or in lieu of, the friction pads **66** of the anchors **46**. As discussed in more detail herein, the reaction pads **88** may include rollers which allow the cutter mechanism **52** to rotate about the axial centerline **72** of the mechanical service tool **12**. The reaction pads **88** may additionally stabilize and/or or provide rigidity to the mechanical service tool **12** by providing a counter force **90** to the force **86** which may be exerted onto the mechanical service tool **12** by the drilling bit **84**. The counter force **90** may prevent axial deflections (e.g., bending in the radial **56** direction) of the mechanical service tool **12** while performing the machining operations on the casing **40**.

(47) Block **90** of FIG. **3** relates to FIGS. **6-10**. In one embodiment, the cutter mechanism **52** may move longitudinally **54** along the tool body **44** of the mechanical service tool **12**. In one embodiment, the anchors **66** may keep the mechanical service tool **12** stationary with respect to the casing **40** while the cutter mechanism **52** moves along the tool body **44**. The cutter mechanism **52** may hence move the drilling bit **84** in the longitudinal **54** direction while the drilling bit **84** may drill into the casing **40**. For example, the cutting tool **12** may house a linear actuator **92** (e.g., a hydraulic cylinder) that may include a piston rod **94**. The piston rod **94** may couple to the cutter mechanism **52**. As such, the linear actuator **92** may apply a force **96** to the piston rod **94** that may move the cutter mechanism **52** and hence the drilling bit **84** longitudinally **54** along the axial centerline **72** of the mechanical service tool **12**. As set forth above, the reaction pads **88** may stabilize the mechanical service tool **12** and the cutter mechanism **52** while still allowing the cutter

mechanism **52** to move in the longitudinal **54** direction with respect to the casing **40**. In another embodiment, the entire mechanical service tool **12** may be moved longitudinally **54** within the casing **40** via movement of the cable **18**. As such, the drilling bit **84** may create elongated axial holes **98** within the casing **40**. In another embodiment, the drilling bit **84** may only partially penetrate the casing **40**, such that the longitudinal **54** movement of the drilling bit **84** within the casing **40** may create elongated axial slots.

(48) In another embodiment, as shown in FIG. **7**, the cutter mechanism **52** may be used to create elongated radial holes **100** and/or elongated radial slots within the casing **40**. The cutter mechanism **52** may couple to the mechanical service tool **12** via rotatable couplings **102** (e.g., bearing assemblies). In one embodiment, the rotatable couplings **102** may allow the cutter mechanism **52** to rotate about the axial centerline **72** of the mechanical service tool **12** while the remaining portions of the mechanical service tool **12** (e.g., tool body **44**, anchors **46**) remain stationary with respect to the casing **40**. The reaction pads **88** may stabilize the mechanical service tool **12** while still allowing the cutter mechanism **52** to rotate. The cutter mechanism **52** may be rotated via a swivel mechanism **106** (e.g., hydraulic motor, electric motor) which may couple to the mechanical service tool **12** (e.g., the anchors **46**). The swivel mechanism **106** may apply a torque **108** to the cutter mechanism **52** which may rotate the cutting head **82** and hence the drilling bit **84** about the axial centerline **72** of the mechanical service tool **12**. In another embodiment, the swivel mechanism **106** may rotate the cutter mechanism **52** at an angle about the axial centerline **72**.

(49) In another embodiment, the mechanical service tool **12** may simultaneously perform the processes shown in FIGS. **6** and **7**. For example, the drilling bit **84** may move longitudinally **54** along the casing **40** and rotate about the axial centerline **74** of the casing **40**. In addition, the linkages **80** may adjust the depth at which the drilling bit **84** may penetrate the casing **40**. This may allow the drilling bit **84** to machine cuts of complex geometry into the casing **40**.

(50) FIGS. **8-10** illustrate a cross-sectional view of the casing **40** and the cutter mechanism **52**. FIG. **8** shows the cutter mechanism **52** in a retracted position within the mechanical service tool **12** (e.g., as shown in FIG. **4**). The reaction pads **88** may include rollers **120** which may move along any direction (e.g., longitudinally **56**, circumferentially) along the interior surface **70** of the casing **40**. In another embodiment, the cutter mechanism **52** may be completely disposed within the mechanical service tool **12** in the retracted position (e.g., the cutter mechanism **52** does not exceed the smallest radial **56** dimension of the mechanical service tool **12**).

(51) FIG. **9** shows the cutter mechanism **52** in an extended position in which the drill bit **84** may apply the force **86** against the casing **40** (e.g., as shown in FIG. **5**). The cutter head **82** may extend from the mechanical service tool **12** and towards the interior surface **70** of the casing **40**. In one embodiment, the drilling bit **84** may penetrate the casing **40** at a desired depth (e.g., to create a slot or penetrate a hole) by altering the force **86** applied to the drilling bit **84**. FIG. **10** shows the cutter mechanism **52** rotating about the axial centerline **72** of the mechanical service tool **12** to create the radial hole **100** and/or elongated slot within the casing **40** (e.g., as shown in FIG. **7**). The torque **108** may rotate the cutter mechanism **52** about the longitudinal **54** axis. Additionally or otherwise, the cutter mechanism **52** and drilling bit **84** may move in the longitudinal **54** direction with respect to the casing (e.g., as shown in FIG. **6**).

(52) Block **110** of FIG. **3** relates to FIG. **11**. In one embodiment, the mechanical service tool **12** may include one or more sensors **112** coupled to the mechanical service tool **12**. As shown in the illustrated embodiment, the one or more sensors **112** may couple to various components of the mechanical service tool **12** such as the tool body **44**, anchors **46**, cutter head **52**, piston rod **94**, or any additional component. The one or more sensors **112** may collect pertinent data (e.g., measure displacement of the piston rod **94**) about the components of the mechanical service tool **12** and transmit said data to the surface via the telemetry (e.g., via electrical or optical signals pulsed through the geological formation **14** or via mud pulse telemetry). As set forth above, the data processing system **28** may process the data collected by the one or more sensors **112**. The one or

more sensors **112** may additionally provide data about the position of the mechanical service tool **12** within the wellbore **16**.

(53) In one embodiment, the mechanical service tool **12** may include a communication and control system **114** which may receive and process a portion or all of the data received by the one or more sensors **112**. The communication and control system **114** may additionally transmit said data to the data processing system **28** via suitable telemetry. In another embodiment, the data processing system **28**, communication and controls system **114**, or an additional system may use the received data to automate a portion, or all of the machining operations set forth herein.

(54) The anchors **46** of the mechanical service tool **12** may be rotary-powered, as described by a method **120** shown in FIG. **12**. In one embodiment, the anchors **46** may also serve as centralizers. In another embodiment, separate centralizers may be used in combination with, or in lieu of the anchors **46**. Block **122** of FIG. **12** relates to FIG. **13**. The mechanical service tool **12** may be lowered to a desired depth within the wellbore **16** and the casing **40**. The anchors **46** may restrict the longitudinal **54** and/or the radial **56** movement of the mechanical service tool **12** within the casing **40**. The friction pads **66** may extend radially **56** from the mechanical service tool **12** towards the interior surface **70** of the casing **40**. In one embodiment, the anchors **46** may include a first caliper **124** and a second caliper **126** that may be operated independently. Although only two calipers are shown in the illustrated embodiment, the anchors **46** may include 1, 2, 3, 4, 5, or more calipers.

(55) Block **128** of FIG. **12** relates to FIG. **14**. A controller **132** may couple to the mechanical service tool **12**. The controller **132** may be operatively coupled to the data processing system **28** and may operate a power unit **134** (e.g., one or more electric motors). The first caliper **124** may couple to a first actuator **136** (e.g., a first threaded rod) and the second caliper **126** may couple to a second actuator **138** (e.g., a second threaded rod). In another embodiment, the first caliper **124** and second caliper **126** may couple to the same actuator. The power unit **134** may actuate the first actuator **136** and/or the second actuator **138**, such that the first actuator **136** may apply a first force **140** to first caliper **124** and the second actuator **138** may apply a second force **142** to the second caliper **126**. For example, the electric motor may be used to rotate the first threaded rod and/or the second threaded rod to apply the first force **140** and the second force **142** respectively.

(56) The first caliper **124** and the second caliper **126** may be used to centralize the mechanical service tool **12** within the casing **40** (e.g., coincide the central axis **72** of the mechanical service tool **12** with the central axis **74** of the casing **40**). As such, the first caliper **124** and the second caliper **126** may apply an equal force (e.g., force **140** and force **142**) against the inner surface **70** of the casing **40**. In another embodiment, the first caliper **124** and the second caliper **126** may offset the axial centerline **72** of the mechanical service tool **12** and the axial centerline **74** of the casing **40**. For example, the first force **140** may be smaller than the second force **142**, such that the mechanical service tool **12** may move radially, perpendicular to the interior surface **70** of the casing **40**. In another embodiment, the first actuator **136** and second actuator **138** may tilt the mechanical service tool **12** at an angle from the longitudinal **54** axis within the casing **40**. The anchors **46** may be positioned above or below the cutter mechanism **52**. In another embodiment, the anchors **46** may be positioned both above and below the cutter mechanism **52**, or at any other position on the tool body **44**.

(57) In another embodiment, the power unit **134** may include a hydraulic system (e.g., hydraulic pump). In the same embodiment, the first actuator **136** and the second actuator **138** may include a first hydraulic cylinder and a second hydraulic cylinder respectively. The hydraulic pump may alter a pressure of hydraulic fluid sent to each the first actuator **136** and the second actuator **138** respectively and hence alter a magnitude of the first force **140** and the second force **142** respectively. In another embodiment, the power unit **134** may be replaced, or used in combination with, an external power unit **144** (e.g., an external hydraulic pump) which may be located at the surface of the wellbore **14**. The external hydraulic pump may supply the hydraulic fluid required to

operate the first actuator **136** and the second actuator **138**.

(58) The mechanical service tool **12** may use an impact system **150**, an example of which is shown in FIG. **15**. The impact system **150** may couple between the drilling bit **84** and the driving motor **85** of the mechanical service tool **12**. The impact system **150** may generate and impart an additional linear impact force and an additional rotational torque to the drilling bit **84**. With the foregoing in mind, it may be useful to first describe one embodiment of the impact system **150**. The impact system **150** may include a housing **152** through which an upper shaft **154** and a lower shaft **156** may extend. The upper shaft **154** may couple to the driving motor **85** and the lower shaft **156** may couple to a chuck **158** which houses the drilling bit **84**. A rotating cap plate **160** may couple to the upper shaft **154**. The rotating cap plate **160** of upper shaft **154** may be guided by upper bearings **162** disposed within the housing **152** and the lower shaft **156** may be guided by lower bearings **164** disposed within the housing **152**.

(59) A spring **166** may be disposed about the upper shaft **154** such that the upper shaft **154** may rotate within a central portion of the spring **166**. The spring **166** may include an upper end portion **168** that may couple to the rotating cap plate **160** and a lower end portion **170** that may couple to an impact weight **172**. The impact weight **172** may couple to an upper hammer **174** that includes angled upper teeth **176**. Both the impact weight **172** and the upper hammer **174** may rotate independently from the upper shaft **154**. The impact weight **172** may be guided by bearings **178** which may be disposed circumferentially between the impact weight **172** and the housing **152**. The lower shaft **156** may couple to a lower hammer **180** that includes angled lower teeth **182**. To facilitate further discussion, the impact system **150** and its components may be described with reference to an axial direction **184** (e.g., the radial **56** direction with respect to the casing **40** of FIG. **2**) and a lateral direction **186** (e.g., the longitudinal **54** direction with respect to the casing **40** of FIG. **2**).

(60) Turning now to FIG. **16**, showing an embodiment of a method **190** of operation of the impact system **150**. Blocks **192** and **194** relate to FIG. **17**. The driving motor **85** may apply a driving torque **196** to the upper shaft **154**. The cutter head **52** may apply the linear force **86** (as shown in FIG. **5**) to the impact system **150**. In the impact system **150**, friction between the drilling bit **84** and the inner surface **70** of the casing **40** may temporarily cause the lower shaft **156** to remain stationary. In this embodiment, the upper teeth **176** of the upper hammer **174** may be held stationary by the lower teeth **182** of the lower hammer **180**. As such, the impact weight **172** may be restricted from rotation.

(61) The upper end portion **168** of the spring **166** coupled to the cap plate **160** may rotate while the lower end portion **170** of the spring coupled to the impact weight **172** may remain stationary. As such, the rotating cap plate **160** may wind (e.g., coil helically) the spring **166**. The winding of the spring **166** may store potential energy in the spring **166**. The spring **166** may decrease in length while being coiled about the upper shaft **154** and may move the impact weight **172** and the upper hammer **174** upwards in the axial **184** direction. As the spring **166** contracts, a gap **195** may form between the upper teeth **176** and the lower teeth **182** of the upper hammer **174** and lower hammer **180** respectively.

(62) Blocks **196** and **198** of FIG. **16** relate to FIG. **18**. Once the gap **195** surpasses a predetermined distance, the upper hammer **174** and lower hammer **180** may rotate such that the upper teeth **176** and lower teeth **182** move to the next position (e.g., engage with a subsequent tooth). As such, the impact weight **172** and the upper hammer **174** may simultaneously descend axially **195** while rotating about the upper shaft **154** as the spring **166** returns to an uncoiled state (e.g., the spring rotates to release the stored potential energy). The stored potential energy of the spring **166** may be transferred as rotational energy (e.g., inertia) to the impact weight **172** and the upper hammer **174**. When the upper teeth **176** and lower teeth **182** reengage, the inertial energy of the rotating impact weight **172** may be transferred to the stationary lower hammer **180** in a small time interval. This may temporarily impart an additional rotational torque **200** to the lower shaft **156** that may be

larger than the driving torque **196** originally provided by the driving motor **85**. Furthermore, the impact weight **172** may generate an additional linear force **202** when the upper hammer **174** engages with the lower hammer **180** and the axial motion of the impact weight **172** is abruptly halted.

(63) As such, the impact system **150** may generate impulses of rotational torque **200** and linear force **202** by storing energy of the driving motor **85** of a specified time frame (e.g., the rate at which the spring **166** coils and contracts). In some embodiments, the rotational torque **200** and the linear force **202** generated by the impact system may be larger than the driving torque **196** generated by the driving motor **85** and/or the force **86** generated by the linkages **80** of the cutter head **82**. FIGS. **15-18** illustrate one embodiment of the impact system **150** and method **190** of operation. However, the first shaft **154** and second shaft **156** may be replaced by a single shaft (e.g., a central shaft). As such, the drilling bit **84** may rotate continuously while the upper hammer **174** and lower hammer **180** coil the spring **166** and store potential energy within the impact system **150**.

(64) FIG. **19** illustrates a jar tool **210** that may couple to the tool body **44** of the mechanical service tool **12**. The jar tool **210** may loosen the mechanical service tool **12** from a constriction within the wellbore **16**. For example, in one embodiment, the geological formation **14** may shift and hence restrict a diameter (e.g., form the constriction) of the wellbore **16**. In this embodiment, the wellbore **16** may pin (e.g., restrict longitudinal **54** movement) the mechanical service tool **12** within the casing **40** and/or the wellbore **16**. The jar tool **210** may loosen the mechanical service tool **12** from the wellbore **16** by providing a longitudinal **54** force to the mechanical service tool **12**.

(65) The jar tool **210** may include a jar body **212** that includes an upper end portion **214** and a lower end portion **216**. In one embodiment, the upper end portion **214** may include threads **218** which may couple the jar tool **210** to the mechanical service tool **12**. In another embodiment, the jar tool **210** may include a downhole tool **220** (e.g., the drilling bit **84**) coupled to the lower end portion **216** of the jar body **212**. As described in greater detail herein, the jar tool **210** may include an anvil **222** (e.g., a spring loaded shuttle) that may deliver an impulse (e.g., a force associated with a sudden change in momentum) to the jar body **212**. The anvil **222** may be accelerated (e.g., via the spring **228**, gravity) and rapidly halted such to create the impulse. The anvil **222** may be accelerated towards the upper end portion **214** or the lower end portion **216** of the jar tool **210** and may hence generate an impact force in the upward longitudinal **54** direction or the downward longitudinal **54** direction respectively. In another embodiment, the anvil **222** may remain stationary while the hammer assembly moves **230** and may provide the impact force. In yet another embodiment, both the anvil **222** and the hammer assembly **230** may move and generate the impact force. The impact force may be transferred to the mechanical service tool **12** via the threads **218** and may free the mechanical service tool **12** from the construction within the casing **40** and/or the wellbore **16**.

(66) In one embodiment, a threaded shaft **224** may protrude through an opening **226** in the anvil **222**. A spring **228** may be disposed within the jar body **212** and may include an upper end portion coupled to a hammer assembly **230** and a lower end portion coupled to a retaining sleeve **232**. As described in greater detail herein, the hammer assembly **230** and/or anvil **222** may generate the impulse, and hence the longitudinal **54** force.

(67) One method **240** that may be used to operate the jar tool **210** appears in FIG. **20**. Block **242** of FIG. **20** relates to FIG. **19**. The anvil **222** may be moved to a staging position (e.g., the upper end portion **214** of the jar tool **210**) such that the anvil **222** may be accelerated and collide with an impact position (e.g., the lower end portion **216** of the jar tool **210**) to create the impact force along the longitudinal **54** direction.

(68) Block **244** of FIG. **20** relates to FIG. **21**, which shows a close up perspective view of the hammer assembly **230** of FIG. **19**. The anvil **222** may be held in the staging position by the hammer assembly **230**. The hammer assembly **230** may include a thread retainer **246** which may

couple to the threaded shaft **224** and move the anvil **222** within the jar body **212**. In one embodiment, a latching ring **248** and a reset ring **250** may couple or decouple the anvil from the threaded shaft **224**. Additionally or otherwise, a hammer **252** may move to the staging position. One or more springs **254** may be used with a position lock **256** to restrict the anvil **222** and/or the hammer **252** in the staging position.

(69) Block **258** of FIG. **20** relates to FIG. **22**, which shows the hammer assembly **230** in a released position. In one embodiment, the hammer **252** may shift the thread retained **246** which may decouple the anvil **222** and/or the hammer **252** from the threaded shaft **224**. In another embodiment, the spring **228** may accelerate the anvil **222** and or the hammer assembly **230** to the impact positon (e.g., the lower end portion **216** of the jar body **212**) which may generate the impact force.

(70) As shown in FIG. **23**, a patching tool **260** may couple to the mechanical service tool **12** or the cable **18**. In one embodiment, the patching tool **260** may patch a hole (e.g., close a void) within the casing **40** (e.g., such as the axial holes **98** or radial holes **100** creates by the drilling bit **84** shown in FIGS. **6** and **7** respectively). The patching tool **260** may include an upper end portion **262** and a lower end portion **264**. In one embodiment, the patching tool **260** may include a threaded adapter **266** near the upper end portion **262** that may couple the patching tool **260** to the mechanical service tool **12**. In another embodiment, the patching tool **260** may couple directly to the cable **18**.

(71) Drive motor **268** (e.g., hydraulic motor, electric motor) may be disposed within the threaded adapter **266** of the patching tool **260**. In another embodiment, the drive motor **168** may couple to the mechanical service tool **12**, or any other portion of the patching tool **260**. The drive motor **268** may couple to a threaded shaft **270** that extends from the upper end portion **262** to the lower end portion **264** of the patching tool **260**. A shuttle **272** configured to move along the threaded shaft **270** may couple to the threaded shaft **270** near the lower end portion **264** of the patching tool **260**.

(72) In one embodiment, a clearance wedge **274** may couple to the threaded adapter **266**. The clearance wedge **274** may guide the patching tool **260** while ascending or descending into the casing **40**. In addition, the clearance wedge **274** may prevent damage to a patching sleeve **276**. In one embodiment, the patching sleeve **276** may be disposed about the threaded rod **270** and extend from the clearance wedge **274** to the shuttle **272**. The clearance wedge **274** and the shuttle **272** may centralize (e.g., coincide a centerline of the patching sleeve **276** with a centerline of the patching tool **260**) the patching sleeve **276** with the patching tool **260**. A nose cone **278** may couple to the lower end portion **264** of the threaded rod **270**.

(73) A method **280** of operating the patching tool **260** is shown in FIG. **24**. Blocks **282**, **284**, and **286** of FIG. **24** relate to FIG. **25**. As described in block **282**, the patching tool **260** may be disposed within the casing **40** of the wellbore **16** such that the patching sleeve **276** is disposed beneath (e.g., radially inward) punctured or weakened areas of the casing **40**. For example, the patching tool **260** may be disposed adjacent to the axial holes **98** or radial holes **100** that may have been previously created by the drilling bit **84**. In another embodiment, the patching tool **260** may be placed adjacent to portions of the casing **40** that may have been damaged by the geological formation **14** (e.g., due to corrosive fluids, abrasion). The nose cone **278** may include rounded edges **288** that may prevent the patching tool **260** from binding with the inner surface **70** of the casing **40** while the patching tool **260** moves within the casing **40**. Additionally or otherwise, the nose cone **278** may protect the patching sleeve **276** from physical contact with the casing **40** while the patching tool **260** moves within the casing **40**. In one embodiment, the clearance wedge **274** may centralize the patching tool **260** within the casing **40**, such that the patching sleeve **276** does not physically contact the inner surface **70** of the casing **40**.

(74) With reference to block **284** of FIG. **24**, the driving motor **268** may rotate the threaded shaft **270** disposed within the patching sleeve **276**. The shuttle **272** may include threads **290** that couple to the threaded shaft **270**. As such, the rotating shaft **270** may longitudinally **54** move the shuttle from the lower end portion **264** to the upper end portion **262** of the patching tool **260** while the

patching tool **260** may remain stationary (e.g., does not move longitudinally **54** within the casing **40**). The shuttle **290** may include a chamfer **292** configured to circumferentially expand the patching sleeve **276** as the shuttle **290** moves from the lower end portion **264** to the upper end portion **262** of the patching tool **260**. In one embodiment, the patching sleeve **276** may be pressed against the interior surface **70** of the casing **40**. The patching sleeve **276** may cover the punctured or weakened areas of the casing **40** (e.g., the axial holes **98**) such that the interior region **42** of the casing **40** may be isolated from the geological formation **14** in which the casing **40** may be disposed.

(75) With reference to block **286** of FIG. **24**, the patching tool **260** may be removed from the casing **40** after the patching sleeve **276** has been circumferentially expanded. In one embodiment, the patching sleeve **276** may remain coupled to the casing **40** through frictional forces between the patching sleeve **276** and the interior surface **70** of the casing **40**. In another embodiment, an adhesive (e.g., bonding glue) configured to retain the position of the patching sleeve **276** with the casing **40** may be applied to the interior surface **70** of the casing **40**, or an external surface of the patching sleeve **276**. The rounded edges **288** of the nose cone **278** may ensure that the patching sleeve **276** is not damaged when the patching tool **260** is removed from the casing **40**.

(76) Turning now to FIG. **26**, a rotary cutter tool **300** may be used in addition to, or in lieu of, the mechanical service tool **12** of FIG. **1**. The rotary cutter tool **300** may couple to a portion of the mechanical service tool **12** (e.g., the tool body **44**) and/or couple to the cable **18**. The rotary cutter tool **300** may be disposed within the casing **40** and may traverse the casing **40** by raising or lowering the cable **18**. In one embodiment, the rotary cutter tool **300** may be disposed directly within the wellbore **16** of the geological formation **14**. As described in more detail herein, the rotary cutter tool **300** may perform additional mechanical operations (e.g., milling, grinding, cutting) within the casing **40** and/or against the formation **14** along the wall of the wellbore **16**. With the foregoing in mind, it may be useful to first describe one embodiment of the rotary cutter tool **300**.

(77) The rotary cutter tool **300** may include a main body **302** that couples to a centralizer section **304** and/or additional subcomponents of the rotary cutter tool **300**. The centralizer section **304** may include one or more centralizing arms **306** that may centralize the rotary cutter tool **300** within the casing **40**. For example, the centralizer section **300** may ensure that an axial centerline **307** of the mechanical service tool **12** and the axial centerline **74** of the casing **40** are concentric. The centralizer section **304** may include an opening system **310** (e.g., a threaded shaft, a hydraulic cylinder) that may radially extend the centralizing arms **306** from the rotary cutter tool **300**. In one embodiment, the centralizing arms **306** may include rollers **311** that allow the main body **302** of the rotary cutter tool **300** to rotate about the central axis **74** of the casing **40**. Additionally or otherwise, the centralizing arms **306** may restrict longitudinal **54** movement of the rotary cutter tool **300** within the casing **40** by applying a force to the interior surface **70** of the casing **40**.

(78) The rotary cutter tool **300** may include a cutting section **312** that performs the mechanical operations within the casing **40**. The cutting section **312** may include a driving motor **314** (e.g., electric motor, hydraulic motor) coupled to a gearbox **316**. In one embodiment, cutting arms **318** including rotating cutters **320** (e.g., circular grinding discs) may extend radially from the cutting section **312**. As described in greater detail herein, the cutters **320** may rotate perpendicular to the central axis **74** of the casing **40** (e.g., about the radial **56** direction) and may advance in a direction parallel to the central axis **74** of the casing **40** (e.g., in the longitudinal **54** direction). The cutting arms **318** may include internal gears that rotationally couple the cutters **320** to the gearbox **316**. Additionally or otherwise, the cutting arms **318** may include a chain drive that couples the cutters **320** to the gearbox **316**. As such, the driving motor **314** may generate a torque to rotate the cutters **320**.

(79) The cutting arms **318** may radially extend from the cutting section **312** towards the interior surface **70** of the casing **40** via actuators (e.g., a threaded rod, a hydraulic cylinder) that move the

cutting arms **318**. In one embodiment, the cutting arms **318** may force the cutters **320** radially **56** outward against the interior surface **70** of the casing **40**. As such, the cutters **320** may machine (e.g., remove material) from the casing **40**. The cutting arms **318** may include a pivot **319** disposed above the cutters **320**. As such, there may be a lesser chance of the rotary cutter tool **300** getting stuck within the casing **40** when removing the rotary cutter tool **300** from the casing **40**, because the cutting arms **318** may have a natural tendency to close when the rotary cutter tool **300** is moved upwards in the longitudinal **56** direction.

(80) In one embodiment, the cutters **320** may completely penetrate the casing **40** and create an axial hole **324** within the casing **40**. Additionally or otherwise, the cutters **320** may only penetrate a portion of the casing **40** such to create axial slots within the casing **40**. In one embodiment, the rotary cutter tool **300** may rotate about the central axis **74** of the casing **40** while the cutters **320** partially or completely penetrate the casing **40**. As such, the rotatory cutter tool **300** may create radial slots or radial holes in the casing **40**. As described in greater detail herein, the rotatory cutter tool **300** may additionally move axially along the central axis **74** of the casing **40** while machining portions of the casing **40**. As such, the rotary cutter tool **300** may alter a thickness of a portion of the casing **40**, and/or completely sever a portion of the casing **40**.

(81) In one embodiment, the cutters **320** may rotate in a direction as indicated by arrows **326**, in which an up-hole portion **328** of the cutters **320** rotate towards the central axis **307** of the rotary cutter tool **300**. As such, the cutters **320** may generate a linear shear force on the internal surface **70** of the casing **40** when the cutters **320** contact the interior surface **70**. This shear force may pull the rotary cutter tool **300** downward in the longitudinal **54** direction. The cable **18** may apply a force **330** that counteracts the linear shear force generated by the cutters **320** and holds the rotary cutter tool **300** stationary within the casing **40** of the wellbore **16**. In one embodiment, the force **330** applied by the cable **18** may be decreased such that the cutters **320** may pull the rotary cutter tool **300** downward in the longitudinal **54** direction. Additionally or otherwise, the force **330** applied by the cable **18** may be increased such that the rotary cutter tool **300** is pulled upward in the longitudinal **54** direction. Thus, the longitudinal **54** movement of the rotary cutter tool **30** may be controlled by slacking or loosening the cable **18**. In one embodiment, a separate device may control the longitudinal **54** movement of the rotary cutter tool **300**, such as a tractor tool.

(82) The rotary cutter tool **300** may include a magnet **332** that collects debris **334** (e.g., metal shavings) that may be generated while the mechanical operations are performed on the casing **40**. As such, the magnet **332** may prevent debris **334** from accumulating within the casing **40**. In one embodiment, a debris basket (e.g., a container coupled below the magnet **332**) may be used in addition to, or in lieu of, the magnet **332**. The debris basket may be disposed below the cutters **320** and collect debris **334** falling from the portion of the casing **40** undergoing machining operations.

(83) In one embodiment, the rotary cutter tool **300** may include an electronics section **338** that houses various electronic components that may be used to control the rotary cutter tool **300**. For example, the electronics section **338** may include a processor that is communicatively coupled to the driving motor **314** and the data processing system **28**. As such, an operator (e.g., human operator, computer system) may control the driving motor **314** of the rotary cutter tool **300** from the surface of the wellbore **16**. In one embodiment, the rotary cutter tool **300** may include one or more sensor that are communicatively coupled to the electronics section **338**. The one or more sensors may monitor operation conditions (e.g., temperature, rotations per minute) of the rotary cutter tool **300** and transmit this information to the electronics section **338** for processing and further transmittal to the data processing system **28**.

(84) A method **340** of operating the rotary cutter tool **300** is shown in FIG. **27**. Blocks **342**, **344**, **346**, and **348** of FIG. **27** relate to FIG. **28**. As described in block **342** of FIG. **27**, the rotary cutter tool **300** may be disposed within the casing **40** using the cable **18**. The cable **18** may move the rotary cutter tool **300** longitudinally **54** within the casing **40** such that the rotary cutter tool **300** may perform the mechanical operations on a desired portion of the casing **40**. As described in block **344**

of FIG. **27**, the centralizing arms **306** may radially **56** extend from the rotary cutter tool **300** and centralize the rotary cutter tool **300** within the casing **40**. The centralizing arms **306** may additionally support the rotary cutter tool **300** while the rotary cutter tool **300** performs the machining operations.

(85) As described in block **346** of FIG. **27**, the cutting arms **318** may radially **56** extend the cutters **320** towards the interior surface of the casing **40**. As described in block **348** of FIG. **27**, the cutters **320** may machine portions of the casing **40**. For example, as shown in FIG. **28**, the cutters **320** may sever and/or disconnect a first section **350** of casing **40** from a second section **352** of casing **40** by severing a threaded connection **354** between the first section **350** of casing **40** and the second section **352** of casing **40**. For example, the rotary cutter tool **300** may sever the threaded connection **354** by radially **56** penetrating the threaded connection **354** using the cutters **320** and subsequently rotating about the central axis **74** of the casing **40**. The rotating cutter tool **300** may additionally move in the longitudinal direction **54** to sever all threads **356** of the threaded connection **354**. In another embodiment, the rotary cutter tool **300** may sever a portion of the casing **40** other than the threaded connection **354**.

(86) When a hole has been created in the casing **40**, a flow control device may be used to regulate the flow of wellbore fluids or formation fluids into the casing **40**. For example, as shown in FIG. **29**, a flow control device **360** may be disposed within the casing **40** and used to regulate a flow of wellbore fluids that may enter the casing **40** from the wellbore **16**. The flow control device **360** may be an integrated component of the casing **40**, coupled to the interior surface **70** of the casing **40**, or coupled to the mechanical service tool **12**. In one embodiment, the flow control device **360** may be disposed over a hole created in the casing **40** (e.g., the axial holes **98** generated by the cutter tool **12** or the rotary cutter tool **300**) in order to regulate the wellbore fluids that may flow through the hole in the casing **40**.

(87) In one embodiment, the flow control device **360** may include a stationary component **362** with slots **364** circumferentially disposed about the stationary component **362**. In one embodiment, the slots **364** may be aligned with the hole in the casing **40** (e.g., the axial hole **98**) and allow wellbore fluids to enter the slots **364** of the stationary component **362**. As discussed in greater detail herein, the flow control device **360** may include a floating element **366** disposed radially inward from an interior surface **368** of the stationary component **364**. In one embodiment, an exterior surface of the floating element **366** may contact the interior surface **368** of the stationary component **362**. The floating element **366** may include additional slots **370** that allow the wellbore fluid to enter the flow control device **360**. As such, in one embodiment, when the slots **364**, **370** are aligned with the hole in in the casing **40** the wellbore fluids may flow from the geological formation **14** through the hole in the casing **40**, the slot **364** of the stationary component **362**, the slot **370** of the floating element **368**, and into an internal space **372** of the flow control device **360**.

(88) In one embodiment, the floating element **366** may rotate within the stationary element **362**. A prime mover **374** may move the floating element **366** within the stationary component **362**. As such, the prime mover **374** may be used to regulate the flow of wellbore fluid in the flow control device by opening, closing, or choking off the flow of wellbore fluid through the slots **364**, **370**. For example, when the slots **364**, **370** are aligned, the wellbore fluids may flow into the casing uninhibited **40**. In one embodiment, when the slots **364** of the stationary component **362** and the slots **370** of the floating element **366** are offset by 90 degrees (e.g., not aligned) no wellbore fluids may flow into the casing **40**.

(89) A method **380** for operating the flow control device **360** is shown in FIG. **30**. Block **382** of FIG. **30** relates to FIG. **29**, in which the flow control device **360** may be disposed within the casing **40** of the wellbore **16** and aligned with the hole in the casing **40**. Blocks **384** and **386** of FIG. **30** relate to FIGS. **31-33**. As set forth above, in one embodiment, the mechanical service tool **12** may operate the flow control device **360** and therefore regulate the flow of wellbore fluids into the casing **40**. For example, the mechanical service tool **12** may be disposed within the wellbore **16**

using the cable **18**. In order to prevent rotation of the mechanical service tool **12**, the mechanical service tool **12** may extend anchors **46** that affix the mechanical service tool **12** to the casing **40**. The mechanical service tool **12** may rotate the prime mover **374** via a gearbox or motor unit coupled to the lower end portion **50** of the mechanical service tool **12**. As illustrated in FIGS. **31-33**, this rotation of the prime mover **374** may regulate the flow of wellbore fluids into the casing **40** by altering the position of the slots **364** within the stationary component **362** and the slots **370** within the floating element **366**.

(90) For example, FIG. **31** illustrates one embodiment of the flow control device **360** in which the floating element **366** is housed within a notch **388** of the prime mover **374**. The floating element **366** may slide with respect to the stationary component **362** and the prime mover **374**. One or more bearings **390** may be disposed between the floating element **366** and the interior surface **368** of the stationary component **362** to reduce frictional effects between the floating element **366** and the interior surface **368**.

(91) The stationary component **360** and the prime mover **374** may include mating threads **392**. As such, when the mechanical service tool **12** rotates the prime mover **374**, the mating threads **392** between the stationary component **362** and the prime mover **374** may axially move the prime mover **374** (e.g., in the longitudinal **54** direction) along the axial centerline **74** of the casing **40**. The prime mover **374** may hence slide the floating element **366** along the interior surface **368** of the stationary component **362**. In one embodiment, the mating threads **392** may generate a large linear force on the prime mover **374** with a modest torque input from the mechanical service tool **12**. In addition, the mating threads **392** may eliminate or avoid the use of large linear actuators that might otherwise be used to move the floating element **366** in other embodiments.

(92) As set forth above, the flow of wellbore fluids into the casing **40** may be regulated by altering the alignment of the slot **364** within the stationary component **362** and the slot **370** within the floating element **366**. For example, if the slots are aligned along a radial **56** centerline, the wellbore fluids may flow into the flow control device **360** and the casing **40** uninhibited. By sliding the floating element **366** longitudinally **54** using the prime mover **374**, the area between the slot **364** and slot **370** available for the wellbore fluids to flow through may be choked and/or eliminated completely.

(93) Additionally or alternatively, the flow control device **360** may include a threaded floating element **396**, as illustrated in FIG. **32**. The threaded floating element **396** may engage directly with the stationary component **362** using the mating threads **392**. As such, the mechanical service tool **12** may rotate the threaded floating element **396** to alter the alignment of the slot **364** within the stationary component **362** and a slot **398** within the threaded floating element **396**. The one or more bearings **390** may be used to reduce frictional effects between the interior surface **368** of the stationary component **362** and the threaded floating element **396**.

(94) Additionally or alternatively, a separate threaded portion **400** may couple to the stationary component **362** using fasteners (e.g., bolts **402**), as shown in FIG. **33**. A threaded floating element **404** may engage with the threaded portion **400** using the mating threads **392**. As such, the cutter tool **12** may rotate the threaded floating element **404** to alter the alignment of the slot **364** within the stationary component **362** and a slot **406** within the threaded floating element **404**. The one or more bearings **390** may be used to reduce frictional effects between the interior surface **368** of the stationary component **362** and the threaded floating element **404**. The threaded floating element **404** may include a notch **408** that engages with a bolt **402** within the stationary component **362**. The notch **408** may thus prevent the threaded floating element **404** from moving past a designated endpoint in the longitudinal direction **54**.

(95) In some situations, it may be desirable to provide energy to sensors or mechanical structures of the mechanical service tool **12**, the rotary cutter tool **300**, or another downhole tool. Turning now to FIG. **34**, a mechanical charging tool **420** may generate electrical energy for downhole tools (e.g., the mechanical service tool **12**, the rotary cutter tool **300**). The mechanical charging tool **420** may

couple, for example, to the mechanical service tool **12**, the rotating cutter tool **300**, or the cable **18**. In one embodiment, the mechanical charging tool **420** may be a component entirely separate of the mechanical service tool **12**. The mechanical service tool **12** may include a power motor **422** (e.g., mud motor, hydraulic motor) that may rotate an input shaft **424** coupled to a generator unit **426** of the mechanical charging tool **420**.

(96) In one embodiment, the generator unit **426** may include an electric generator **428** that directly converts the rotational energy of the input shaft **424** to electrical energy. In one embodiment, the generator unit **426** may include a rotating mass **430** that is spun and/or accelerated via the input shaft **424**. The rotating mass **430** may store rotational kinetic energy. In one embodiment, the rotational kinetic energy of the rotating mass **430** may be used to spin the electric generator **428** while the input shaft **424** may be stationary. Additionally or otherwise, the mechanical charging tool **420** may include a spring **432** that is wound (e.g., coiled helically) using the input shaft **424**, similarly to the kinetic energy stored in the rotating mass **430**. As such, potential energy may be stored in the spring **432**. The spring **432** may be unwound and used to spin the generator **428**, such that the generator **428** may generate electrical energy.

(97) In addition, the spring **432** may be compressed linearly to store elastic potential energy. This energy may be stored and released using a mechanical trigger. For example, the elastic potential energy in the spring **432** may be converted to rotational movement using a crank system when the spring **432** expands linearly. As such, the spring **432** may rotate an input shaft of the generator **428** a generate electrical energy. The mechanical charging tool **420** may include a power outlet **434** and output leads **436**. The output leads **436** may be coupled to components (e.g., the sensors **112**) of the mechanical service tool **12** that may require electrical power.

(98) FIG. **35** illustrates a method **440** that may be used to operate the mechanical charging tool **420**. Block **442** of FIG. **35** describes the input of rotational mechanical energy into the mechanical charging tool **420**. For example, the input shaft **424** may accelerate the rotating mass **430** within the mechanical charging tool **420** and store rotational potential energy using the inertia of the mass **430**. Additionally or otherwise, the input shaft **424** may coil the spring **432** within the mechanical charging tool **420**. As such, the mechanical charging tool **420** may store various forms of potential energy.

(99) Block **444** of FIG. **35** describes releasing the stored potential energy and/or converting the stored potential energy to electrical energy that may power components of the mechanical service tool **12**. For example, the rotating mass **430** may be used to rotate the generator **428**, ergo transforming the rotational kinetic energy of the rotating mass **430** into electrical energy. Similarly, the stored potential energy in the coiled spring **432** may be release when the spring **432** is unwound and used to rotate the generator **428**. The generated electricity may be supplied to various components of the mechanical service tool **12** (e.g., the sensors **112**) using the output leads **436**.

(100) The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

Claims

1. An impact system of a mechanical service tool, the impact system comprising: a first shaft configured to be coupled to a driving motor; a second shaft configured to be coupled to a drilling bit; an impact weight disposed within a housing; a spring coupled to the impact weight and the housing, wherein the spring is configured to coil about or compress along an axis; and a hammer mechanism including: a first hammer coupled to the impact weight, the first hammer having a first plurality of teeth; and a second hammer coupled to the second shaft, the second hammer having a

second plurality of teeth that are engageable with the first plurality of teeth, wherein the hammer mechanism is configured to engage the second shaft with the driving motor and disengage the second shaft from the driving motor by selectively engaging the second plurality of teeth with the first plurality of teeth based on coiling action of the spring.

2. The impact system of claim 1, wherein the first shaft extends through an opening of the impact weight, wherein the impact weight is configured to impart an impact axially while a torque is transferred by the first shaft, and wherein the impact weight is configured to retract slower than the impact weight extends to release energy stored axially in the spring.

3. The impact system of claim 1, wherein the impact weight is freely movable in an axial direction.

4. The impact system of claim 3, wherein: the spring is coupled to the first shaft and configured to provide compressive force to the impact weight; and the impact weight is coupled to the first shaft and configured to store rotational energy.

5. The impact system of claim 3, wherein the impact weight is configured to transmit torque to the second shaft with successive torque spikes by alternatively storing and releasing spring energy.

6. The impact system of claim 1, further comprising sensors configured to measure operational parameters of the driving motor.

7. The impact system of claim 1, further comprising a computer configured to monitor and control operation of the impact system in real time.

8. The impact system of claim 6, further comprising a surface system configured to receive sensor data transmitted from the sensors.

9. A method comprising: rotating a shaft of an impact system using a driving motor; winding or compressing a spring about an axis, based on a first plurality of teeth of a first hammer being engaged with a second plurality of teeth of a second hammer, wherein the shaft is disposed within a central portion of the spring; unwinding or extending the spring about the axis based on the first plurality of teeth becoming disengaged with the second plurality of teeth, wherein the spring is configured to accelerate an impact weight; and decelerating the impact weight, wherein the impact weight is configured to impose a force on a drilling bit.

10. The method of claim 9, wherein the impact weight is configured to release energy in a direction of a drilling bit axis.

11. The method of claim 9, wherein the impact weight is configured to release energy in a rotary manner to provide successive torque spikes.

12. The method of claim 9, further comprising reengaging the first plurality of teeth with the second plurality of teeth, wherein decelerating the impact weight is based on reengaging the first plurality of teeth with the second plurality of teeth.

13. A method, comprising: engaging a first plurality of teeth of a first hammer with a second plurality of teeth of a second hammer; rotating a first shaft using a driving motor; winding a spring based on rotating the first shaft; moving an impact weight and the first hammer away from the second hammer, based on winding the spring, so as to disengage the first plurality of teeth from the second plurality of teeth; unwinding the spring based on the first plurality of teeth disengaging from the second plurality of teeth; accelerating the impact weight toward the second hammer, based on unwinding the spring; and decelerating the impact weight, wherein the impact weight imparts a force to a drill bit based on decelerating the impact weight.

14. The method of claim 13, further comprising rotating the impact weight concurrent with accelerating the impact weight, wherein the force imparted by the impact weight to the drill bit includes a linear impact force and a rotational torque.

15. The method of claim 13, further comprising reengaging the first plurality of teeth with the second plurality of teeth.

16. The method of claim 15, wherein: engaging the first plurality of teeth with the second plurality of teeth comprises engaging a first tooth of the first plurality of teeth with a first tooth of the second plurality of teeth; and reengaging the first plurality of teeth with the second plurality of teeth

comprises engaging the first tooth of the first plurality of teeth with a second tooth of the second plurality of teeth that is different than the first tooth of the second plurality of teeth.

17. The method of claim 13, wherein decelerating the impact weight comprises the first hammer impacting the second hammer.

18. The method of claim 17, further comprising reengaging the first plurality of teeth with the second plurality of teeth based on the first hammer impacting the second hammer.

19. The method of claim 17, wherein the impact weight imparts a linear impact force and a rotational torque to the drill bit via impact of the first hammer with the second hammer.