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DRILL BIT DATA MANAGEMENT FOR PENETRATION-MONITORING DRILL

Abstract

Embodiments directed to an apparatus and system of monitoring an instrument with a working tool engaged thereby. In one aspect, an embodiment including a working tool with a machine readable indicium indicative of a working tool attribute. The working tool may be receivable by an instrument such that a corresponding machine readable indicia reader receives an identifier of the working tool. Various attributes and conditions in relation to the instrument and working tool received thereby may be identified to facilitate the provisioning of a response to prompt various corrective actions. In this regard, a controller may provide an output in response to a received identifier of a working tool and an identified instrument operating condition.

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Background/Summary

RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 18/155,652, filed on Jan. 17, 2023, titled "DRILL BIT DATA MANAGEMENT FOR PENETRATION-MONITORING DRILL," which is a continuation of U.S. application Ser. No. 16/765,560, filed on May 20, 2020 and now issued as U.S. Pat. No. 11,576,684 titled "DRILL BIT DATA MANAGEMENT FOR PENETRATION-MONITORING DRILL," which is a 371 National Stage entry of PCT/US2018/062181 filed Nov. 21, 2018 titled "DRILL BIT DATA MANAGEMENT FOR PENETRATION-MONITORING DRILL," which claims the benefit of U.S. Provisional Application No. 62/589,230 filed Nov. 21, 2017, entitled "DRILL BIT DATA MANAGEMENT FOR PENETRATION-MONITORING DRILL," the contents of all of which are incorporated by reference herein as if set forth in full.

FIELD
[0002] The present invention generally relates to powered surgical instruments, and in particular to powered surgical instruments that releaseably engage a working tool to perform an operation.
BACKGROUND
[0003] Various powered surgical instruments (e.g., drills, saws, grinders, etc.) may be associable with a plurality of corresponding working tools (e.g., drills bits, saw blades, grinding burrs, etc.) to facilitate certain operations using the powered surgical instruments. For example, a handheld drill may engage any one of a plurality of drill bits in order to bore a hole through a medium of interest such as an anatomical structure of a patient. Further, in such settings, each of the plurality of working tools may embody certain attributes including but not limited to a certain size, serial number, material composition, manufacturer, temperature tolerance, and the like. For example, a first respective drill bit may constitute a first bore diameter and a first material made by a first manufacturer, while a second respective drill bit may constitute a second bore diameter and a second material made by a second manufacturer. In this regard, the operation of the instrument including the functionality, specifications, and limitations related thereto may be at least partially based on the particular respective working tool engaged by the powered surgical instrument. That is, the specific attributes of the engaged working tool may at least partially inform or otherwise impact the functionality of the instrument, for example, by defining the operational limitations of the instrument in relation to the engaged working tool. In this regard, the first respective drill bit with the first bore diameter and first material may limit the rotational speed, for example, at which the instrument may be used to bore a hole, etc.
[0004] Further, some electro-mechanical instruments may include one or more sensors integrated therein to measure various conditions of the instrument and/or of the operational environment thereof such as the density of a medium through which a working tool is advanced during use. In this regard, in such circumstances, the values measured by the one or more sensors of the instrument and any outputs related thereto may be at least partially based on the particular engaged working tool and its associated attributes. As such, with regards to the foregoing, it may be desirable to identify the particular engaged working tool and the attributes related thereto.

SUMMARY
[0005] In view of the foregoing, the present disclosure facilitates a system for monitoring an instrument and a working tool engaged by the instrument. The instrument may be a powered surgical instrument and the working tool may be used in conjunction with the powered surgical instrument for performing an operation. The system may facilitate generation of an output or signal from an indicia reader responsive to detection of an indicium associated a working tool. An indicium may be indicative of or associated with a working tool attribute and/or instrument operating condition. The invention allows a user of the instrument to effectively manage a system in which a plurality of working tools may be engageable by the instrument so as to identify relevant information in relation to a respective working tool engaged by the instrument. The invention further allows the user to identify relevant information in relation to one or more measureable or determined conditions associated with the instrument that may prompt or otherwise facilitate corrective or other remedial action.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0006] FIG. **1** depicts an embodiment of a monitoring system for monitoring an instrument and working tool engaged thereby.
[0007] FIG. **2** is a functional block diagram of a controller and instrument for use in a system for monitoring an instrument, according to one embodiment.
[0008] FIG. **3** is a functional block diagram of an access terminal for use in a system for monitoring an instrument, according to one embodiment.
[0009] FIGS. **4** and **5** illustrate various screenshots of embodiments of a user interface displayable via a portal of a system for monitoring an instrument.
[0010] FIG. **6** illustrates with a flow diagram an embodiment of a method for monitoring an instrument.
[0011] FIG. **7** is an elevation view, partially in cross section of an embodiment of a real-time, drill bit penetration measuring system.
[0012] FIG. **8**A is a sectional view of bone illustrating a prior art method of using a drill mechanism to create a bicortical path through a cortical bone having multiple layers.
[0013] FIG. **8**B is a sectional view of a bone illustrating a prior art method of using a drill mechanism to create a unicortical drill path through the outer layer of a cortical bone.
[0014] FIG. **9**A is an enlarged sectional view of the embodiment of the drill bit load measurement assembly of FIG. **7**.
[0015] FIG. **9**B is a sectional view of a portion of the drill bit load measurement assembly taken along the line **9***b*-**9***b* of FIG. **9**A.
[0016] FIG. **10**A is an enlarged sectional view of an embodiment of the drill bit load measurement assembly of FIG. **7**.
[0017] FIG. **10**B is a sectional view of a portion of the drill bit load measurement assembly taken along the line **10***b*-**10***b* of FIG. **10**A.
[0018] FIG. **11** is an elevation view of an embodiment of a control panel of a controller assembly of FIG. **7**.
[0019] FIG. **12** is a schematic block diagram of the controller assembly of FIG. **7** and the inputs and outputs of the controller assembly.
[0020] FIGS. **13**A, **13**B, and **13**C are diagrams illustrating the position of the drill bit of FIG. **7** in bicortical bore of FIG. **8**B and the corresponding output of the first and second sensors of the displacement and load measurement assemblies of FIG. **2**.
[0021] FIG. **14** is a flow diagram of an embodiment of a method for determining the depth of

penetration of a drill bit.

[0022] FIGS. **15**A and **15**B depict an embodiment of a controller for use in operation of a drill having a drill bit penetration measurement system.

[0023] FIGS. **16**A, **16**B, and **16**C are perspective, side, and front views, respectively, of an embodiment of a drill comprising a drill bit penetration measurement system.

[0024] FIG. **17** is a perspective view with a partial cutaway of a drill body of an embodiment of a drill comprising a drill bit penetration measuring system.

[0025] FIG. **18** is a cross sectional schematic view of a drill bit that has been advanced into a bore in a medium relative to a bushing engaged with a distal portion of a displacement sensing arm.

DETAILED DESCRIPTION

[0026] Disclosed herein are utilities (e.g., systems, processes, etc.) for monitoring an instrument operatively associated with a working tool. In this regard, the disclosed utilities include a working tool having a machine readable indicium associated with at least one working tool attribute. The working tool may be receivable by the instrument, for example, via operation of a chuck or other receiving element operable to receive or otherwise secure and engage the working tool therein. Upon receipt of a working tool, a corresponding machine readable indicia reader may analyze the indicium to determine an identifier associated with the working tool. The identifier may be used to retrieve a working tool attribute from a database or may directly convey a working tool attribute. For example, in the former instance, the identifier may comprise a serial number which may be used to identify working tool attributes. In the latter instance, the identifier may directly indicate a working tool attribute such as a manufacturer thereof. The machine readable indicia reader may transmit an identifier, the same as or different than the identifier received at the machine readable indicia reader, to a controller for processing. The disclosed utilities may also include a displacement measuring apparatus (or other appropriate measuring apparatus) disposed in corresponding relation to the working tool to measure displacement of the working tool relative to an axis along which the working tool may be advanced during use. In some instances, additional or alternative measuring apparatuses may be provided, as discussed below. The disclosed utilities may also include a controller (mentioned above) in operative communication with the instrument and configured to provide an output responsive to a working tool attribute received, for example, from a database. The output may be displayed to a user on a display monitor or may be transmitted to the instrument to influence the operation thereof.

[0027] Working tool attributes may be utilized in many respects. In some cases, a working tool attribute may be used to maintain an inventory of working tools. For example, a current inventory present at a hospital or other site may be automatically maintained wherein a quantity is reduced upon the reading of an indicium associated with a particular type of working tool represented by the quantity. As another example, each working tool used during an operation may be entered into a list such that upon completion of the operation, personnel may take inventory of working tools brought into the operating room to verify that all working tools are accounted for.

[0028] Additionally, working tool attributes may be monitored to ensure safe operation of an instrument. For example, a particular instrument may be prevented from operating unless and until one or more attributes of a working tool associated therewith have been verified as compliant with required specifications. As another example, an instrument may be disabled upon a determination, based upon an indicium associated with the working tool, that the working tool is not new from the factory but rather has been used with another patient or has been refurbished by an unlicensed party.

[0029] Finally, working tool attributes may be recorded in a database of surgical operation statistics to improve medical procedures. For example, during an operation, a drill may record operating conditions such as force applied, motor speed, and displacement into a patient's bone. This information may be recorded in conjunction with demographics about the patient and attributes associated with the drill bit utilized. In this regard, determinations may be made regarding optimal

drill bit size, materials, and methods of use.

[0030] Certain terminology is used in the following description for convenience only and should not be considered as limiting. The words "inwardly" and "outwardly" refer to directions toward and away from, respectively, the geometric center of the systems and designated parts thereof described herein. The terminology includes the words above specifically mentioned, derivatives thereof and words of similar import.

[0031] Additionally, as used in the claims and in the corresponding portion of the specification, the word "a" means "at least one," the word "about" when used in conjunction with a numerical value means a range of values corresponding to the numerical value plus or minus ten percent of the numerical value, and the word "or" has the meaning of a Boolean inclusive "Or." For example, the phrase "A or B" means "A" alone or "B" alone or both "A" and "B."

[0032] As used herein, the term "instrument" may refer to any tool or device, powered or manually operated, which is configured for use with a removable and replaceable part referred to herein as a working tool. For example, an instrument may be a drill, a saw, a screwdriver, etc. and a working tool may be a drill bit, a saw blade, a screwdriver bit, etc. A machine readable indicium may be any device or marking that is capable of being read, interpreted, analyzed, or otherwise received by a machine. For example, a machine readable indicium may be a radio frequency identification (RFID) tag, a bi-directional sensor, a barcode, a QR code, an alphanumeric identifier, etc. Notably, a machine readable indicium need not be readable by machine only but may also be readable by a user. A machine readable indicia reader may be any device configured to observe, scan, read, or otherwise detect a machine readable indicium. For example, a machine readable indicia reader may be an RFID reader, an optical sensor, a laser scanner, camera, etc.

[0033] Machine readable indicia may be configured to convey a working tool attribute directly or may convey an identifier which can be used to look-up working tool attributes from a database stored locally or remotely. For example, a machine readable indicium may convey an identifier such as a serial number to the machine readable indicia reader. The machine readable indicia reader, or a device in operative communication therewith such as a controller, may then reference a database to retrieve working tool attributes associated with the serial number. Notably, "working tool attributes" as that term is used herein in reference to information received at a controller or instrument from a database may refer to working tool attributes themselves or may refer indications of working tool attributes. To illustrate, a database may convey to a controller that a particular identifier sent from the controller to the database is associated with a size "3" drill bit. The numerical value "3" may then be conveyed to the controller which references a data repository to determine that a size "3" drill bit is 4 inches long and has a ⅛″ diameter. In this regard, "3" may be considered an indication of a working tool attribute rather than a working tool attribute itself. Working tool attributes may include a working tool size, a working tool serial number or other identifier, a material from which the working tool is constructed, a manufacturer of the working tool, any prior uses of the working tool, an optimum, maximum, or minimum instrument operating speed associated with the working tool, or any other relevant information concerning the working tool.

[0034] The term "identifier" as used herein may refer to any information which is conveyed by an indicium and useful for determining a working tool attribute. In some instances, an identifier may itself be, or may directly convey, a working tool attribute and in other instances, an identifier may be an alphanumeric sequence with working tool attributes encoded therein. A controller may decipher the identifier to determine the working tool attributes.

[0035] A controller, as that term is used herein, may be any device having or associated with a processing engine which is operable to monitor an instrument, display properties associated with the instrument, and/or control operation aspects of the instrument. In some instances, a controller may be integrated directly into an instrument, it may be disposed adjacent an instrument and in operative communication therewith, or may be disposed remotely and configured for

communication with the instrument via a wired or wireless network. A controller may be operable to receive an identifier from a machine readable indicia reader and reference a local or remote database to retrieve working tool attributes associated with the identifier. In response to receiving certain working tool attributes, a controller may be configured to allow an instrument to operate using the respective working tool or may prevent the instrument from operating. For example, if a working tool attribute indicates that a working tool has previously been used with another patient, a controller may prevent a drive motor of the instrument from receiving control signals, thereby disabling the instrument. A default status of a drive motor may be set by a controller to "operative" such that the instrument will work unless and until a working tool attribute is determined to be unacceptable. Alternatively, a default status of a drive motor may be set by a controller to "inoperative" such that the instrument will not work unless and until all working tool attributes considered critical are determined to be acceptable. The determination of whether a working tool attribute is acceptable or unacceptable may be executed using a series of rules (discussed below).

[0036] Broadly, the disclosed embodiments relate to monitoring an instrument that is operatively associable with any one of a plurality of working tools. This may be desirable, for example, in environments in which each of a plurality of working tools exhibits different attributes which, in turn, influence the operation or use of the instrument. In this regard, the operative association of one of the plurality of working tools with the instrument may facilitate reading an indicium disposed at the working tool and associated with or directly communicating one of the particular attributes of the working tool. In this regard, the invention may be used for identifying a working tool attribute of interest of a received working tool so that a controller may provide an output responsive to the identified working tool attribute of interest. Such an output may be a signal to enable or disable the instrument or a component thereof, may be a signal to trigger an alarm or alert to the user, for example, indicating that the working tool may be undesirable for the instant operation, or may affect an operating condition of the instrument. For example, a working tool attribute indicating a maximum drive speed of 100 RPM may result in the controller outputting a signal that limits the drive motor in the instrument to 100 RPM. A working tool attribute may be received or selected at a controller by referencing a database using the identifier transmitted by the machine readable indicia reader. For example, the machine readable indicium may be disposed in proximal relation to the machine readable indicia reader such that the machine readable indicia reader transmits an identifier corresponding to the indicium. In this regard, as each working tool may include a respective machine readable indicium, the controller may provide an output responsive to characteristics or properties of the respective working tool received at the instrument.

[0037] In certain other embodiments, described below, the disclosed utilities also include a data collection module operatively associated with a displacement measuring apparatus for identifying an instrument operating condition. "Instrument operating condition" may refer to a condition corresponding to the operation of the instrument itself, the operating environment of the instrument, and/or any other conditions or parameters of interest that may facilitate monitoring an instrument, according to the embodiments described herein. For example, the data collection module may include or utilize a processor for identifying an instrument operating condition at least partially based on a measured displacement of the working tool. For example, the present invention may determine a condition corresponding to the operating condition of the instrument, such as the density of an environment through which the working tool is advanced during use. Such a determination may be made based upon a measured force applied to the working tool, the displacement of the working tool, and working tool attributes.

[0038] In other embodiments, a processor may identify an instrument operating condition at least partially based on a working tool attribute received by the instrument or controller. For example, by receiving a known weight of the working tool, the processor may be able to determine a magnitude of torque being applied to the working tool by the instrument.

[0039] In some instances, the instrument operating condition may facilitate monitoring an

inventory level of working tools that are associable with the instrument. This may occur, for example, by counting the instances of a working tool attribute received which correspond to unique working tools over a period of time and correlating the received working tool attributes to determine an inventory level. For example, a database may be used to store a dynamic count of each time a working tool is used having a particular attribute, such as a ⅜″ diameter. In this regard, the count may be increased by manual or automatic entry of a quantity of working tools received in a delivery and may be decreased by one each time a uniquely identified working tool having the attribute of interest is used.

[0040] It should be appreciated, however, that alterative or additional measuring apparatus embodiments may be utilized in accordance with the present invention, which may be used to identify the instrument operating condition or provide other information of interest. For example, in addition or in the alternative to the disclosed displacement measuring apparatus, the instrument may include a rotational measuring apparatus disposed in corresponding relation to the working tool to measure rotational characteristics of the instrument such as angular velocity, angular frequency, torque, etc. A processor may obtain measured rotational characteristics of the instrument for identifying an instrument operating condition. As another example, the instrument may include a power systems measuring apparatus disposed in corresponding relation to a drive mechanism of the instrument to measure characteristics in relation to the operation of the working tool such as voltage and current fluctuations, powers, resistance, efficiency, run-time limitations, such as overheating, etc. A processor may obtain the measured characteristics of the instrument for identifying an instrument operating condition. In yet other embodiments, other measuring apparatuses are contemplated for measuring one or more characteristics of the instrument to facilitate the functionality of the disclosed monitoring system. Accordingly, the description below should be understood as exemplifying particular embodiments and implementations of the invention, and not by way of limitation.

[0041] Reference will be now be made to the accompanying drawings, which assist in illustrating the various pertinent features of the various novel aspects of the present disclosure. The following description is presented for purposes of illustration and description. Furthermore, the description is not intended to limit the inventive aspects to the forms disclosed herein. Consequently, variations and modifications commensurate with the following teachings, and skill and knowledge of the relevant art, are within the scope of the present inventive aspects.

[0042] In this regard, FIG. **1** presents a schematic representation an embodiment of a system **100** for monitoring an instrument that may include a working tool **102** with a machine readable indicium **104**. In this regard, the machine readable indicium **104** may be indicative of a working tool attribute corresponding to the working tool **102**. For example, the machine readable indicium **104** may be indicative of one or more working tool attributes of the working tool **102**. In some instances, a machine readable indicium **104** may convey a first attribute such as an identifier which may be used to identify or retrieve additional attributes.

[0043] According to another embodiment, the system **100** may include a plurality of working tools **102** each with a respective machine readable indicium **104**. In turn, the respective machine readable indicium **104** may be indicative of or associated with a working tool attribute corresponding to the respective working tool **102** with which the respective machine readable indicium **104** is associated. Accordingly, based in part on the machine readable indicium **104** facilitating the identification of a working tool attribute, the various characteristics or properties of the working tool may be communicated to an instrument or other associated hardware to, for example, identify the working tool **102** and facilitate the provision of an output responsive to a working tool attribute received in relation to the machine readable indicium **104**.

[0044] The system **100** for monitoring an instrument may also include an instrument **106** with a machine readable indicia reader **108**. In this regard, the machine readable indicia reader **108** may receive an identifier associated with working tool **102** via machine readable indicium **104**. For

example, working tool **102** may be received by the instrument **106** such that the machine readable indicia reader **108** receives an identifier associated with the working tool via the operative association of the machine readable indicia reader **108** with the machine readable indicium **104**.

[0045] The machine readable indicium **104** may be disposed in proximal relation to the machine readable indicia reader **108** such that machine readable indicia reader **108** receives the identifier of the working tool via signal **110**. In this regard, signal **110** may be an electromagnetic signal generated at the machine readable indicium **104** in part by an induced magnetic field at the machine readable indicia reader **108** (as may be the case for a passive RFID tag transferring electronically stored information to an RFID reader that produces a magnetic field). In other cases, signal **110** may include an optical signal for registration by the machine readable indicia reader **108**.

[0046] Accordingly, based on the received identifier of the working tool, the instrument **106** may identify a particular received working tool **102** along with the characteristics or properties related thereto. That is, the system **100** may include a plurality of working tools **102**, with each working tool **102** including a respective machine readable indicium **104** indicative of one or more working tool attributes associated with the respective working tool **102** at which the machine readable indicium is disposed. The instrument **106** may be associable with any of the plurality of working tools **102**. In this regard, the instrument **106** may identify or otherwise register the particular working tool attributes associated with the respective engaged working tool **102** upon receipt of the working tool **102** at the instrument **106**. The identification of the particular working tool attributes of the working tool **102** at the instrument **106** may be processed at the instrument **106** and/or transmitted from the instrument **106** to facilitate the provision of an output responsive to the received identifier and/or identification of the instrument operating condition.

[0047] The system **100** for monitoring an instrument may also include a controller **112** in operative communication with the instrument **106** via electronic signal **114**. In this regard, the controller **112** may provide an output responsive to the received identifier. For example, the instrument **106** may include an antenna and/or other output device for transmission of electronic signal **114** to controller **112** such that controller **112** may provide an output based at least in part on the information received via the electronic signal **114**. As such, the electronic signal **114** may carry or otherwise convey information associated with the working tool attribute and/or other characteristics, parameters, or conditions associated with the instrument **106** such that the controller **112** may provide an appropriate corresponding output. The output may be communicated, for example, via a user portal, local display, and/or other output element to facilitate monitoring the instrument **106** and corresponding working tool **102**. Preferably, such communications of the electronic signal **114** are wireless. In this regard, the instrument **106** and controller **112** may each include an RF transceiver for conducting wireless communications in accordance with a public or proprietary protocol such as a WAN, a LAN, and/or the internet. The electronic signal **114** may also be communicated between the instrument **106** and the controller **112** via a wireline connection. In some embodiments, a controller may be at least partially disposed within a housing of an instrument and the electronic signal **114** may accordingly be contained within the instrument.

[0048] In this regard, the controller **112** may facilitate monitoring the instrument **106** by providing an output responsive to an identified instrument operating condition, discussed in greater detail below. That is, the controller **112** may provide any appropriate output to prompt, for example, corrective or other responsive actions by a user of the system **100**. For example, the controller **112** may provide an output responsive to a received working tool attribute that indicates an inventory level corresponding to a plurality of working tools **102**, which may prompt a user to take a corrective action in relation to the indicated inventory level such as ordering additional units. As another non-limiting example, the controller **112** may provide an output responsive to a received or determined instrument operating condition that indicates one or more characteristics corresponding to the environment in which the received working tool **102** advances during use.

[0049] In certain other embodiments, the controller **112** may be in operative communication with a

remote server (not pictured) to facilitate analysis of the information received via electronic signal **114** in relation to one or more correlation factors determined at the remote server. For example, the correlation factors may be determined at the remote server based on communications received from a plurality of controllers. Notably, each of the plurality of controllers may be in operative communication with a respective instrument (or a plurality of instruments) and configured to collect data in relation to one or more parameters of the respective instrument or environment related thereto. In turn, this collected data may be transmitted to the remote server for determination of a correlation factor for application in subsequent utilizations of the instrument **106**. In this regard, the controller **112** may provide an output responsive to a received identifier and/or identified instrument operating condition with respect to an instrument correlation factor determined at the remote server. The correlation factor may represent a threshold factor with which a measured value of the instrument **106** is compared to facilitate the identification of the instrument operating condition, etc. Turning next to FIG. **2**, a detailed functional block diagram of system **100** is depicted in which various data attributes such as working tool attributes, instrument operating conditions, sensor values, and the like may be transmitted between the instrument **106** and the controller **112** to facilitate monitoring the instrument **106** and the working tool **102** received thereby. Broadly, the system **100** and the various components therein may include any appropriate hardware (e.g., computing devices, data centers, switches, antennas, etc.), software (e.g., logic, computer readable instructions, applications system programs, engines, etc.), network components (e.g., communication path interfaces, routers, etc.), and the like (not necessarily shown in the interest of clarity) for use in facilitating any appropriate operations of the network.

[0050] According to one embodiment, controller **112** and instrument **106** are configured for operative communication via electronic signal **114**. Electronic signal **114** may be wired, wireless, or may be integrated into an instrument. Electronic signal **114** may be transmitted over one or more optional data networks **116** in order to support the disclosed monitoring of instrument **106**. In this regard, the controller **112** may be provided locally to generate a response to facilitate real-time corrective actions, such as when indicating an environmental condition through which a received working tool **102** is advanced during use or may be provided remotely to generate a response to facilitate system remediation, such as when indicating an inventory level of a plurality of working tools **102** that are associable with the instrument **106**, etc. In some instances, an access terminal **118** may be provided for bi-direction communication with the instrument **106** and the controller **112** via the one or more data networks **116**. The access terminal **118**, discussed in greater detail below, may facilitate providing the output responsive to the received identifier and/or the instrument operating condition by presenting the provided output of the controller as a visual or interactive display, etc.

[0051] The instrument **106** may generally employ various components to receive an identifier of a working tool and facilitate the provisioning of an output responsive to the received identifier. The instrument **106** may also include various components to identify an instrument operating condition and facilitate the provisioning of an output related thereto. In this regard, the instrument **106** may include machine readable indicia reader **108** operatively connected to and controlled by processing engine **120**. Processing engine **120** may be integrally included with instrument **106** to execute various modules or engines of the instrument **106**, including facilitating the operation of various associated sensors or other data collection and analysis devices.

[0052] The instrument **106** may include one or more modules designed to collect and/or process information to facilitate the provision of a responsive output at the instrument **106**, controller **112**, or other connected output device. As such, in the illustrated embodiment, the instrument **106** may include a first sensor **122** and a second sensor **124** configured to measure one or more parameters of interest. In this regard, the first and second sensors **122**, **124** may be embodied as a measuring apparatus for identifying one or more characteristics of the instrument **106**. For example, the first or second sensor **122**, **124** may correspond to a sensor for use in a displacement measuring apparatus. In other embodiments, the first or second sensor **122**, **124** may correspond to a sensor

for measuring the rotational characteristics of the received working tool **102**, a sensor for measuring the power characteristics of the instrument **106** such as voltage and current fluctuations, power efficiency, etc. or any other sensor for measuring a parameter of interest such as a force sensor configured to monitor an amount of force exerted by a user to advance an instrument. In this regard, an output from the first and second sensors **122**, **124** may be provided to the processing engine **120** as an electronic signal for manipulation, processing, and/or transmitting according to the embodiments described below.

[0053] For example, the instrument **106** may also include data collection module **126** operatively associated with the processing engine **120** and first and second sensors **122**, **124** for identifying an instrument operating condition. In this regard, data collection module **126** may obtain data collected at first and second sensors **122**, **124** via processing engine **120** to identify the instrument operating condition.

[0054] Various parameter values or combinations of parameter values may be utilized to identify the instrument operating condition—the precise value, however, may vary depending on various factors, including the particular received working tool **102**, the environment of the instrument **106**, and/or the instant operation or application, as may be specified or pre-programmed by a user of the system **100**. In one embodiment, in which first sensor **122** includes a sensor for use in a displacement measuring apparatus, information associated with the force applied at the working tool **102**, information associated with the displacement of working tool **102** (i.e., relative to an axis along which the working tool **102** is advanced during use), and/or derivatives thereof may be utilized to identify an instrument operating condition indicative of, for example, a density of a material through which the working tool is advanced during use. In some instances, it may be desirable to process the identified instrument threshold values or algorithms such that the instrument **106** may provide an output that prompts a user to take one or more corrective actions.

[0055] In relation to the above instrument operating condition indicative of density, for example, it may be desirable to generate an alarm via actuation of alarm module **130** (discussed in greater detail below) if the instrument **106** attempts to advance a working tool **102** through an environment consisting of a density that exceeds a predetermined value, such as 5.00 or 5.50 g/cm.sup.2. Alternatively, an alarm may be generated based on an abrupt increase or decrease in density such as more than .5 g/cm.sup.2 in one second or several seconds, for example. As another alternative, an alarm may be generated based on a combination of these parameters such as density is rising at more than .5 g/cm.sup.2 per second and density exceeds 5.00 g/cm.sup.2. It will be appreciated that such thresholds or related algorithms may be based on the particular application of the instrument **106**, and may incorporate the various expertise, experience, and evolving standards of a user of system **100**. It will be appreciated that additional or alternative instrument operating conditions along with associated threshold values and corresponding alarms may be determined at least partially analogous to the manner described above, including instrument operating conditions determined based on information received from other described embodiments of first and second sensors **122**, **124** and information in relation to a received identifier.

[0056] To facilitate the foregoing generation of an alarm or other responsive output, various parameter values may be utilized, for example, to quantify a threshold condition, range, etc. In this regard, the foregoing parameter values may be stored in a local database in the instrument **106** such as storage **128**. The storage **128** may include information for use by the processing engine **120** and data collection module **126** in executing the noted functionality. For example, the storage **128** may include standardized operating parameters or other attributes in relation to the instrument **106** and/or the received working tool **102**, threshold values or algorithms to facilitate determination of alarm conditions, environmental conditions, and any other appropriate data attributes for determining when an alarm should be triggered. This information may be stored prior to use of the instrument **106** or may be updated via wireless or other methods via electronic signal **114**, for example, transmitted over the one or more data networks **116**.

[0057] The processing engine **120** may implement a variety of different algorithms for obtaining values such as those measured by first or second sensor **122**, **124**, identifying an instrument operating condition, and/or determining whether an alarm should be triggered. Such algorithms may involve simple comparison of values, such as comparing a current displacement value to a displacement value threshold. Alternatively, such algorithms may involve accessing one or more parameters from a remote server in order to facilitate the analysis of the obtained measured values, as discussed in greater detail below. For example, the processing engine **120** may determine a threshold displacement value appropriate for the instant operating conditions of the instrument **106** in part by reference to a remote central processor that provides a correlation factor based in part on aggregated information received from a plurality of instruments.

[0058] The alarm module **130** of instrument **106** may include an audio alarm, vibrating devices, wireless alerts, updated or other notifications via phone applications, a visual alarm, or any other system for alerting a user to the identified instrument operating condition. For example, the alarm module **130** may include LEDs, audio tone generators, or the like. In the case of the instrument **106** embodied as a handheld tool, visual alarms such as illuminating an LED when a threshold condition is reached may be particularly useful in notifying a user of an instrument operating condition. Accordingly, the alarm module **130**, through one of the foregoing described techniques, may alert a user to the identification of an instrument operating condition or other determined output. In this regard, as the user is alerted to the instrument operating condition, the user may take appropriate corrective actions or be prompted by a third party to do so. For example, an alarm indicative of a target displacement of the working tool **102** may prompt the user to stop advancement of the working tool **102**.

[0059] The instrument **106** may also include communication module **132** to facilitate the bidirectional communication between the instrument **106** and controller **112**. For example, the communication module **132** may include an RF transceiver for conducting wireless communications. In other instances, the communication module **132** may include a port or other hardwired connection to facilitate wireline communications. In either event, the communication module **132** is configured to transmit and receive electronic signal **114** via the one or more data networks **116**.

[0060] In some embodiments, the instrument **106** may also include a battery **134** operable for providing power to the instrument **106** and each of the associated processors, modules, and sensors included therein. In some instances, the battery **134** may be recharged by a recharge module **136**, which may include a re-charge induction coil and/or a port for connecting to an AC power source or other recharging power source.

[0061] As described above, the instrument **106** may transmit one or more electronic signals to the controller **112** to facilitate the described monitoring of instrument **106** and received working tool **102**. Accordingly, the controller **112** may include various components and modules to receive and transmit data with the instrument **106** to facilitate the foregoing functionality. In the illustrated embodiment, as depicted in FIG. **2**, the controller **112** may include a memory **138** (e.g., RAM, other volatile modules, etc.) that contains one or more modules or engines that process data received from the one or more data networks **116**; a processing engine **140** that executes the modules or engines from the memory **138**; storage **142** (e.g., one or more magnetic disks, solid-state drives, or other non-volatile memory modules) for storing received and generated data; communications module **143**; and a number of other components **144** (e.g., input devices such as a keyboard and a mouse, a transceiver in operative communication with the communications module **143** for transmitting and receiving electronic signals to and from the instrument **106**, other devices such as a display and speakers, and the like), all of which may be appropriately interconnected by one or more system buses **146**.

[0062] The one or more engines of the controller **112** may generally facilitate processing of data received via the one or more data networks **116** for monitoring of the instrument **106** and storing

the resultant data in one or more databases of storage **142**. Each of the engines may be in the form of one or more sets of computer readable instructions for execution by the processing engine **140**, and may be manipulated by a user in any appropriate manner to analyze and configure the measured, received, or generated data as disclosed herein. Each of the engines may also be manipulated to configure the data stored in the one or more databases of storage **142** for transmission via the one or more data networks **116**. In this regard, the combination of processing engine **140**, memory **138**, and/or storage **142**, and the various engine/modules disclosed herein in one embodiment create a new machine that becomes a special purpose computer once it is programmed to perform particular functions of the utilities disclosed herein. While various engines have been depicted in FIG. **2** as being separate and distinct engines, it is understood that the functionalities or instructions of two or more engines may actually be integrated as part of the same computer-readable instruction set, and that the various engines have been depicted in the manner shown in FIG. **2** merely to highlight various functionalities of the system.

[0063] In one arrangement, the controller **112** may include a data collection module **148** that receives incoming data over the one or more data networks **116** for executing one or more processing functions and storing the received and/or processed data in storage **142** in any appropriate manner. In this regard, storage **142** may include a thresholds/conditions database **150** for storing various parameter values for use in identifying the instrument operating condition, etc.; a past performance database **152** for storing historical data and metrics associated with previously identified instrument operating conditions, including past and current inventory levels of a plurality of working tools **102** associable with the instrument **106**, etc.; and a user database **154** for storing data associated with various users of the instrument **106**, etc. In this regard, the controller **112** may also include a database builder **156** that is configured to manipulate the received and/or processed data to create, structure, or otherwise format the various databases of storage **142**. In this regard, the database builder **156** may be configured to structure the various data attributes stored in storage **142** to facilitate the monitoring of instrument **106** and identification of an instrument operating condition. In this regard, the database builder may structure received data attributes of the thresholds/conditions database **150** in corresponding relation to various anticipated measured data attributes to facilitate identification of a corresponding instrument operating condition, etc.

[0064] As discussed above, controller **112** may include data collection module **148**. According to one embodiment, data collection module **148** may perform substantially all of the functions described with respect to data collection module **126** of instrument **106**, including the generation of an alarm output in relation to an identified instrument operating condition. In this regard, the data collection module **148** may be configured for identifying an instrument operating condition based on, for example, a measured data value obtained via the first or second sensors **122**, **124**. Additionally, the data collection module **148** may be configured for receiving an identifier of a working tool. In this regard, the data collection module **148** may receive data measured or generated at the instrument **106** for identifying the instrument operating condition and/or a working tool attribute.

[0065] The data collection module **148** may facilitate the identification of any instrument operating condition of interest as may be specified or otherwise preprogrammed, for example, by a user in relation to a particular use case, etc. In some instances, the identification of an instrument operating condition may involve accessing one or more databases of storage **142** for comparison or analysis with one or more measured or generated data attributes of the instrument **106**. According to one embodiment, the instrument operating condition may include a condition indicative of a condition-dependent status of the instrument **106**. For example, the condition-dependent status may be indicative of a physical condition of the instrument **106**. In this regard, for the sake of non-limiting example, the condition-dependent status may correspond to the physical condition of a drive system of the instrument **106**. The data collection module may therefore be configured to identify such instrument operating condition, for example, by comparing a data value measured at first

sensor **122** (e.g., the operating temperature of the drive system) with an accessed data value of the thresholds/conditions database **150** (e.g., corresponding to a normal operating temperature range for the drive system). Accordingly, the condition-dependent status may be at least partially based on this comparison of values (e.g., the condition-dependent status may indicate that the noted drive system "Needs Servicing" or any other appropriate indicators in relation to the foregoing comparison).

[0066] In yet another embodiment, the instrument operating condition may be indicative of an inventory-dependent status. As noted, in some instances, the working tool **102** may be one of a plurality of working tools associated with the system **100**, each receivable by the instrument **106**. In this regard, it may be desirable for a user of the system **100** to receive an indication in relation to the quantities of working tools **102** of the plurality of working tools remaining within the system **100** for associable use with the instrument **106**. To facilitate the foregoing, the data collection module **148** may receive data over the one or more data networks **116** corresponding to identifiers received at the instrument **106**. For example, the identifier may be a working tool serial number that uniquely identifies the respective working tool **102** received by the instrument **106**. The unique identification of the working tool may, in turn, be compared against a predetermined inventory level of working tools in order to account for the use of the instant received working tool **102**.

[0067] In some embodiments, a machine readable indicium on a working tool may be read by a machine readable indicia reader **108** of an instrument **106** which generates or transmits an indication of an identifier associated with the working tool and more specifically, with the machine readable indicium. In this regard, the identifier may be a serial number or any other unique identification mechanism associated with the working tool to distinguish the particular working tool from other, perhaps similar, working tools. In this sense, the word "unique" is intended to indicate only that the identifier is unique within a given set of working tools and need not be entirely unique in a global sense.

[0068] Upon engagement of a working tool with an instrument **106**, the identifier (e.g., serial number) of the working tool may be read and stored in a database. Such a database may be locally disposed in the instrument **106** or in a controller **112** associated with the instrument **106**, remotely disposed in a database in operative communication with a plurality of instruments, or in a global database in communication with all instruments capable of engaging the working tools described herein, for example. The identifier of a given engaged working tool may be referenced against such a database prior to operation of the instrument **106**. In this regard, if the identifier is found in a database which contains identifiers of previously used working tools, certain conditions may be placed upon operation of the instrument **106**. For example, if a working tool is considered to be a one-time use or disposable device, then the instrument **106** may be prevented from operation based upon a determination that an engaged working tool has been previously used, locally or remotely (such as with another instrument at another facility). In the case that a working tool is designated or approved for only a single use, such as in a thresholds/conditions database, any subsequent attempts to utilize the working tool after an initial registration with an instrument may be denied by a controller. As another example, certain working tools may be restricted to a single patient or may be associated with a maximum operational life. In the former regard, each time a working tool is engaged with an instrument **106** (or more or less frequently), a database may be referenced to determine if the given working tool has been used on another patient. If so, the instrument **106** may be prevented from engaging the drive motor based on a control signal, or lack thereof, received from the controller **112**. In the latter regard, each time an instrument is operated, the time elapsed during use may be recorded in a database which maintains total use times of each working tool. A rule (stored for example, in thresholds/conditions database **150**) may be used to establish a maximum operational life such that at any time the total use time of a particular working tool reaches or exceeds the maximum operational life, all instruments associated with that working tool may be prevented from further operation if the working tool is engaged therewith.

[0069] A controller **112** may be operable to send a request to a remote server including a working tool identifier. The remote server may utilize the identifier to process rules, lookup data associated with the identifier, and/or transmit an output back to the controller **112**. In response to receipt of the output, the controller **112** may be operable to restrict or permit operation of the instrument **106**. Alternatively, a remote server may not be utilized. Rather, the controller **112** may itself be operational to lookup data associated with a working tool identifier, to process rules which determine operation limitations, and implement policies in accordance with the rules to permit or restrict operation of the instrument **106**. For example, the controller **112** may be in operative communication with a drive motor of the instrument **106**. In the absence of the receipt of a working tool identifier at the controller **112** (which may indicate a counterfeit, unapproved, improperly refurbished, or otherwise incompatible working tool), or in the event that an identifier is associated with an unacceptable condition (e.g., the working tool has been previously used and is therefore incompliant with standards of care), the controller **112** may prevent engagement of the drive motor. Similarly, a rule may indicate that the identifier is associated with a limited operating speed. In response, the controller **112** may limit the speed of the drive motor of the instrument **106**.

[0070] In still other embodiments, a database of standard operations, such as surgical procedures or medical operations may be maintained locally or remotely. A user may select a standard operation at an access terminal **118** in communication with a given instrument **106** or set of instruments. The standard operation may be associated with a set of rules or other specifications regarding working tools that may be used in accordance with standard operating procedures. For example, a particular type of operation (e.g., ACL reconstruction) may require or otherwise be associated with working tools having a particular material composition, a particular manufacturer, a given range of diameters and/or lengths, etc. for compliance with regulations or standards of care. In this regard, an instrument may be associated with an operation, for example, by manual data entry into the access terminal. Upon engagement of a working tool with the instrument, the database may be referenced to determine if the attributes of the working tool engaged with the instrument are compatible with the instrument and/or meet the specifications of the operation. If the attributes comply with the requirements of the operation, a drive motor of the instrument may be allowed to operate. If one or more attributes of the working tool, as determined based upon the identifier, do not comply with the requirements of the operation, the drive motor may be prevented from engaging and/or an alert to the user may be triggered.

[0071] In some instances, working tools or other medical devices used during surgery may become misplaced and in a few cases, may be unintentionally deposited within a surgical site of a patient. In order to ensure all working tools are accounted for upon completion of a procedure, inventory may be taken. To facilitate such inventory accounting, a list of working tools used during a procedure may be maintained in a local or remote database. Upon completion of the procedure, the list may be used to manually or automatically take inventory of used working tools. For example, each working tool engaged with an instrument used during the procedure may have a unique identifier which is maintained in a list of used working tools. The list may be presented to a user on a display of an access terminal for manual verification that all used working tools are accounted for. Additionally or alternatively, a machine readable indicia reader (either disposed in an instrument or independently) may be utilized to scan or otherwise read the machine readable indicium of each working tool collected upon completion of the procedure. If an identifier is present on the list of used working tools (thereby indicating the associated working tool was used during the procedure) but the working tool associated with the identifier is not scanned upon completion of the procedure, an alert may be triggered to the user via an instrument, a controllers, access terminal, etc. In certain other embodiments, the instrument operating condition may be indicative of an environment through which the working tool **102** is advanced during use, including one or more characteristics of the environment such as environment density. In this regard, the data collection module **148** may process one or more data attributes measured by, for example, the first

or second sensors **122**, **124** in order to obtain information in relation to the environment through which the working tool **102** is advanced. For example, according to one embodiment, the first sensor **122** may be configured to measure the displacement of the working tool **102** relative to an axis along which the working tool **102** is advanced during use. Additionally, the second sensor **124** may be configured to measure the force presently applied at the working tool **102**. In this regard, the instrument operating condition, as identified by the data collection module **148**, may be at least partially based on the measured displacement of the working tool **102** and the measured forced applied at the working tool **102**.

[0072] As such, the instrument operating condition may be indicative of a density of the environment through which a working tool of the instrument is advanced during use. In this regard, the instrument operating condition may dynamically change with the operation of the instrument **106**. For example, the working tool **102** may be advanced through an environment with a variable density or through an environment with several discrete changes in density. As such, the instrument operating condition may be compared in real time to one or more data values which may be stored, for example, in thresholds/conditions database **150** in order to facilitate the provision of an alarm output in relation to the identified instrument operating condition. For example, as described above in relation to alarm **130**, an alarm output responsive to the comparison of the identified instrument operating condition with the one or more parameter values may alert a user to a condition of interest and/or prompt a user to take various corrective actions.

[0073] To illustrate the foregoing, consider that the instrument **106** may be embodied as a surgical instrument disposed for measuring the displacement of a received working tool **102** relative to an exterior surface of a surgical site during a surgical operation. In this regard, the working tool **102** may be embodied as a surgical drill bit. Accordingly, the instrument operating condition may be configured to be indicative of a bone density. As will be described in greater detail below, the particular value of the bone density through which the working tool **102** is advanced may be indicative of various stages of a surgical procedure involving various stratums of tissue, as depicted in greater detail in FIGS. **13**A-**13**C). In this regard, the instrument operating condition may support aspects of the surgical operation by alerting the user to particular changes in bone density that may prompt various corrective actions.

[0074] In some instances, the particular value of the instrument operating condition may be compared for analysis with one or more threshold values in order to provide an alarm output corresponding to a condition of interest. That is, one or more threshold values or conditions may be associated with a change in bone density that prompts the corrective action by the user. Notably, however, the particular threshold value of bone density may be different for each subject of a medical operation based on demographics, medical conditions and history, or other individualized characteristics. Accordingly, the data collection module **148** may be operable to associate the instrument operating condition with one or more health history characteristics of the subject. That is, the data collection module **148** may access one or more particular health history characteristics of the particular subject undergoing the surgical operation to determine a threshold value for the instrument operating condition in order to facilitate the provision of an alarm or other appropriate output. In this regard, the data collection module **148** may compare the instrument operating condition to a particular subject's health history characteristic, which may include a subject's age, weight, sex, nationality, geographic location, medication history, disease history, and/or any other appropriate characteristic that may facilitate the identification of an appropriate threshold value for comparison with the instrument operating condition indicative of bone density. In some instances, this may include execution of one or more algorithms as described above in relation to alarm module **130** of instrument **106**.

[0075] In certain other embodiments, the controller **112** may also include analytics engine **158** in operative communication with the data collection module **148** and configured to analyze the identified instrument operating condition and/or the received identifier as identified or received at

either the controller **112** or the instrument **106**. For example, the analytics engine **158** may generate one or more metrics displayable at a user portal, in order to facilitate the disclosed monitoring of instrument **106**. In this regard, the analytics engine **158** may provide information for use in taking corrective actions in response to the identified instrument operating condition and/or received identifier. Furthermore, the controller **112** may also include a portal **160** such as an Internet or web-based platform to facilitate transmitting information associated with identifying the instrument operating condition and/or the working tool attribute to access terminal **118**. In some embodiments, the controller **112** may receive data from the access terminal **118** via the one or more data networks **116**.

[0076] In another embodiment, the controller **112** is one of a plurality of controllers **112** that collectively communicate to form a distributed network. In this regard, each of the plurality of controllers **112** may be in operative communication with a central processing server (not pictured) remote from the plurality of controllers **112**. Each of the plurality of controllers **112** may also be in operative communication with a respective instrument **106** or a plurality of instruments and able to identify an instrument operating condition and/or received identifier associated with the respective instrument. As such, information from each of the controllers **112** may be sent to the central processor to analyze one or more parameters. For example, each of the controllers **112** may transmit information to the central processor in relation to a particular identified instrument operating condition of interest, such as bone density for a respective subject undergoing a surgical operation with the respective instrument, etc.

[0077] By way of continued example, the controller **112** may transmit the measured bone density with regards to identified subjects that correspond to the specified medical history of the patient. In this regard, the central processor may aggregate such information in order to determine an aggregate threshold value for identifying an instrument operating condition value that will facilitate the provision of an alarm output for a subject with similar medical history characteristics. For example, this aggregated value may result in the determination of one or more correlation factors that may be transmitted to one or more controllers. In this regard, upon the subsequent operation of the instrument **106**, the controller **112** may be configured to generate a response based on an identified instrument operating condition as analyzed with respect to the received correlation factor. As such, the controller **112** may leverage the information received at the central processor in order to more accurately identify the instant instrument operating condition. This may be accomplished by executing a predictive algorithm based on the correlation factor to predict an instrument operating condition in a particular use case of the instrument **106**, for example.

[0078] The embodiments of a controller **112** and instrument **106** are provided for exemplary illustration only. Certain components illustrated in FIG. **2** as being part of instrument **106** may optionally be disposed in controller **112**. For example, processing engine **120** may be the same as processing engine **140**. In this regard, all operation of the instrument may be processed by processing engine **140** of the controller **112** which may or may not be disposed within instrument **106**. Furthermore, data collection module **126** may be data collection module **148**, communications module **132** may be communications module **143**, and storage **128** may be storage **142**. Furthermore, alarm **130** may be disposed within controller **112**.

[0079] Turning next to FIG. **3**, a more detailed functional block diagram of the access terminal **118** for use in receiving and transmitting information with the controller **112** is depicted. The access terminal **118** may generally employ various components to receive and transmit information. In this regard, as shown, the access terminal **118** may include a display **162** that presents information associated with the controller **112** to a user via a user interface **164**; processing unit **166** configured to process received information; memory **168**; and storage **170** for storing received and/or processed information. Additionally, the access terminal **118** may be configured to receive input **172** in response to information presented on display **162** and transmit output **174** which may be indicative of a request for information from the controller **112**, etc., In this regard, the controller

112 may transmit information between the portal **160** and the access terminal **118** via the one or more data networks **116**. For example, this may occur by any appropriate browser (not shown) running on the memory **168** of the access terminal **118** that may appropriately access the portal **160** via the one or more data networks **116**.

[0080] Reference will now be made to a number of representative screen shots of the portal **160** that may be presented on, for example, display **162** of the access terminal **118** and that may be manipulated by a user to configure the monitoring of the instrument **106** as described in detail below. It should be understood that the various functionalities disclosed herein are not limited to use with such specific screenshots as presented. Rather, the screen shots are merely provided to facilitate the reader's understanding of the various programs, modules, and other functionalities disclose herein.

[0081] Starting now with FIG. **4**, a screenshot **400** is depicted in which a working tool report **402** is displayed. Broadly, the working tool report **402** may include various configurations of information for use in identifying an instrument operating condition, such as an inventory-dependent status. As noted, the respective working tool may be one of a plurality of working tools receivable by the instrument **106**. In this regard, it may be desirable to present information in relation to the usage of the plurality of working tools.

[0082] According to one embodiment, the working tool report **402** may include inventory level monitoring graph **404** for use in displaying the foregoing information in a graphical format. In this regard, the inventory level monitoring graph **404** may include a time axis **406** (shown extending generally along an x-axis in the illustrative example) and an inventory level axis **408** (shown extending generally along a y-axis in the illustrative example).

[0083] To illustrate the foregoing, the inventory level monitoring graph **404** may include one or more graphical lines. For example, the inventory level monitoring graph **404** may include aggregate working tool inventory line **410** indicative of an aggregate inventory level of the plurality of working tools which may indicate a total count of the plurality of working tools available for association with the instrument, as filtered by various user criteria as a function of time. According to one embodiment, each received identifier of a respective working tool at the instrument may facilitate the identification of the inventory-dependent status of the instrument operating condition. For example, the data collection module may decrease the inventory-dependent status for each received identifier which is indicative of the working tool being utilized such that it cannot subsequently be associated with the instrument **106** after the instant use. In this regard, the aggregate working tool inventory line **410** may generally decrease over a period of time with each subsequent use of a respective received working tool, as represented with respect to the time axis **406**. Alternatively, the aggregate working tool inventory line **410** may periodically increase. For example, the identified inventory-dependent status may be updated based on a restocking or resupply of the plurality of working tools.

[0084] The inventory level monitoring graph **404** may facilitate the dynamic or substantially real-time monitoring of the inventory-dependent status via the aggregate working tool inventory line **410**. For example, the aggregate working tool inventory line **410** may include current inventory level **412**. In this regard, the inventory level monitoring graph **404** may provide an indication to a user of the system indicative of the inventory level of working tools associable with the instrument **106**. In some instances, the current inventory level **412** may be accompanied by a floating box **414** operable to provide additional information in relation to the current inventory level **412**. In this regard, according to one embodiment, the floating box **414** may include current inventory status indicator **416**.

[0085] More generally, working tool report **402** may include other indicators or visual modules to facilitate the dynamic or substantially real-time monitoring of the inventory-dependent status. For example, the working tool report **402** may include "zero" inventory indicator **418** configured to provide an indication in relation to the estimated time until the current inventory level **412** will be

equal to zero units (assuming that additional working tools **102** are not subsequently added to the plurality of working tools **102**). In this regard, the zero inventory indicator **418** may be based on a variety of measured and determined factors including the rate at which the inventory of the plurality of working tools **102** is depleted. In some instances, the rate at which the plurality of working tools **102** is depleted may be represented at inventory level monitoring graph **404** by anticipated inventory level line **419**. In this regard, the anticipated inventory level line **419** may be configured to project the aggregate inventory level based on an analysis of historical inventory levels which may include reference to data stored at past performance database **152**, etc. Accordingly, the foregoing functionalities may prompt a user to take corrective actions to facilitate maintenance of an appropriate inventory level of the plurality of working tools **102** associable with the instrument **106**.

[0086] Such corrective actions may be facilitated by the functionality of the working tool report **402**. For example, the working tool report **402** may include reordering button **420** to facilitate the replenishment of the inventory level of the plurality of working tools **102**. In this regard, the reordering button may be manipulated by a user to increase the inventory level. In this regard, reordering button **420** may include initiate bar **422** configured to accept a response from a user that causes initiation of a preprogrammed ordering protocol. As such, the inventory level may be manually increased by the manipulation of the initiate bar **422**. In this regard, in some instances, manipulation of the initiate bar **422** may trigger a variety of events, such as, placing an order for the additional inventory, assigning the inventory to a physical location, and/or other appropriate logistical functions.

[0087] Furthermore, the reordering button **420** may also include predictive bar **424** configured to accept a response from a user that causes initiation of a preprogrammed ordering protocol to automatically increase the inventory level of the working tools **102**. For example, the data collection module **148** may monitor one or more parameters displayable at the working tool report **402** in order to determine an appropriate time at which to initiate a preprogrammed ordering protocol to increase the inventory level of the plurality of working tools **102**.

[0088] Working tool report **402** may also facilitate displaying information in relation to various working tools **102** of interest. In this regard, the working tool report **402** may include detail inventory display **426** configured to display various details associated with a particular, or subset of, working tools **102** of the plurality of working tools **102**. In the illustrated embodiment, the detail inventory display **426** may include a serial no. column **428**, a size column **430**, a material column **432**, a case no. column **434**, and an inventory column **436**. It will be appreciated, however, that in other embodiments, more or less columns may be included at the detail inventory display **426** as may be appropriate and/or of interest to a user in relation to the characteristics of a particular working tool **102**.

[0089] Consider, for the sake of illustration, row **426***a* of detail inventory display **426**, which displays various information attributes associated with a working tool **102** uniquely identified by serial number 17483, according to serial number column **428**. In particular, row **426***a* includes information pertaining to various characteristics of the working tool **102** identified by serial number 17483. For example, the working tool identified by serial number "17483" may be associated with a size of "⅜ inch" and be associated with a material of "Titanium SS". In some cases, the working tool **102** may be prospectively assigned to a use case (e.g., a planned use of the working tool **102** for a particular case or scenario, such as a particular planned surgery, etc.). In this regard, the working tool **102** identified by serial number 17483 may be associated with prospective use case number "10578". In some instances, the data value depicted at the case no. column **434** may be manipulable by a user such that additional information may be presented in relation to the respective use case number. In other words, manipulation of the value of the case number value No. 10578 may present information to a user in relation to an upcoming surgery during which the working tool **102** identified by serial number 17483 may be scheduled for use, etc.

[0090] In some instances, the user may desire to obtain information pertaining to the inventory level of a particular subset of working tools **102**. In this regard, the user may manipulate a "Report" link in row **426***a* in order to display information in relation to an inventory-dependent status corresponding to the plurality of working tools that share one or more particular characteristics of the working tool **102** identified by serial number 17483. In this regard, the detail inventory display **426**, may facilitate the provision of additional information in relation to the inventory level of working tools with characteristics similar to the characteristics of the working tools **102** listed at the detail inventory display **426**.

[0091] Additionally, the information displayed at the inventory level monitoring graph **404** may be manually filtered according to the preferences of a system user. In this regard, the working tool report **402** may include a filter inventory results button **438** configured to facilitate the presentation of information at inventory monitoring graph **404** in relation to the desired preferences. In this regard, the filter inventory results button **438** may include a size field **440**, a material field **442**, a manufacture field **444**, and a weight field **446**. Accordingly, each of the foregoing fields may be operable to accept a response from a user in order to facilitate the presentation of information at the inventory level monitoring graph **404** relative to the accepted responses. It will be appreciated that in some instances more or fewer fields may be configured to accept a user response according to the particular embodiment. Additionally, all fields associated with the filter inventory results button need not receive a response from a user in order to facilitate the foregoing filtering functionality.

[0092] According to the illustrated embodiment, the filter inventory results button **438** may accept a response in relation to a working tool size of "⅜ in", a working tool material of "Cobalt", a working tool manufacture of "ABC Corp.", and a working tool weight of "Light". As such, based on the foregoing received responses of the illustrated embodiment, manipulation of the filter inventory results button **438** may cause the inventory level monitoring graph **404** to display information associated with the inventory level of the subset of the plurality of working tools **102** that correspond to a size of ⅜ inch, a material of Cobalt, a manufacture of ABC Corp. and a weight of Light. In turn, each of the various metrics and other analytics devices described above may be updated to reflect the manipulation of the filter inventory results button **438**.

[0093] Turning next to FIG. **5**, a screenshot **500** is depicted in which instrument monitoring report **502** is displayed which may facilitate the dynamic or near real-time monitoring of the instrument **106** and/or the environment through which a received working tool **102** is advanced during use, etc. Broadly, the instrument monitoring report **502** may include various configurations of information for use in displaying information in relation to an identified instrument operating condition, for example, such as the density of the material through which the working tool **102** is advanced during use. As previously described, the identified instrument operating condition may be at least partially based on data obtained from first and second sensors **122**, **124** of the instrument **106** such as data indicative of a measured force applied at the working tool **102**, data indicative of a measured axial displacement of the working tool **102**, etc. In this regard, the instrument monitoring report **502** may be configured to present information to a user in relation to such measured data and metrics determined in relation thereto, which may prompt a user to take corrective action based on the presented information during use of the instrument **106**, etc. For example, presenting information in relation to the density of the material through which the working tool **102** is advanced during use may facilitate various corrective actions in relation to the use of the instrument **106**.

[0094] According to one embodiment, the instrument monitoring report **502** may include density graph **504** for use in displaying an instrument operating condition indicative of the density of the material through which the working tool **102** is advanced during use. It will be appreciated, however, the density graph **504** is only one illustrative embodiment of the contemplated functionality of the instrument monitoring report **502**. In other embodiments, the instrument monitoring report **502** may include other graphs of various different identified instrument operating

conditions corresponding to a condition of the instrument analogous to the functionality described herein. For example, a graph may be presented in relation to power consumption, maintenance indicator levels, and the like. In this regard the density graph **504** may include a time axis **506** and an environment density axis **508**.

[0095] To illustrate the foregoing, the density graph **504** may include one or more graphical lines. For example, the density graph **504** may include anticipated density line **510** indicative of an anticipated density of the environment through which the working tool **102** is to be advanced during a particular use case. Additionally, the density graph **504** may include measured density line **512** indicative of a measured density of the environment through which the working tool **102** is advanced during use. The measured density line **512** may be based at least in part on measured values obtained at the first and second sensors **122**, **124**, such as forces measured at the working tool **102** and the displacement of the working tool.

[0096] The information displayed at the density graph **504** may correspond to a particular use case of the instrument **106**. That is, the instrument **106** may be used for particular defined task for which the instrument operating condition is identified and analyzed. In this regard, the density graph **504** may display the anticipated density line **510** and the measured density line **512** in relation to the time or sequence of events of the particular use case. For example, at least the measured density line **512** may be displayed in relation to a start time **514** of the use case. In this regard, the start time **514** may correspond to the initiation of the particular use case of the instrument **106**. As such, the measured density line **512** may increase and decrease in relation to the time axis **506** as initiated at the start time **514**. The measured density line **512** may conclude at current measured density **516** indicative of the currently measured density. In this regard, as the density graph **504** may include information about the present operating condition and/or environment of the instrument **106**, a user may be prompted to take corrective actions by reference to the information contained therein.

[0097] In some instances, the current measured density **516** may be accompanied by floating box **518** configured to provide additional information in relation to the currently measured density **516**. In this regard, according to one embodiment, the floating box **518** may include current measured density indicator **520** to numerically indicate to a user the value of a currently measured density **516** presented at density graph **504**. More generally, the density graph **504** may facilitate the comparison of a measured value with an anticipated or projected series of values. In some instances, this may be embodied as a visual comparison between various graphical lines depicted at the density graph **504**. In yet other instances, the instrument monitoring report **502** may provide one or more metrics to facilitate the foregoing comparison. For example, according to the illustrated embodiment of FIG. **5**, the floating box **518** may include a deviation from projected value indicator **522** to numerically indicate a percentage deviation of the measured density line **512** with the anticipated density line **510**. Accordingly, the floating box **518** may prompt the user to take one or more corrective actions based on the information contained therein.

[0098] Additionally, the instrument monitoring report **502** may include summary information button **524** configured to provide one or more data parameters or characteristics in relation to the particular use case corresponding to the information depicted at the density graph **504**. In this regard, the summary information button **524** may include a case no. field **526**, a risk profile field **528**, a material field **530**, and a criticality field **532**. Accordingly, each of the foregoing fields may be configured to indicate information in relation to the instrument operating condition as depicted at density graph **504**. It will be appreciated that in some instances, more or fewer fields may be configured to indicate information in relation to the particular use case.

[0099] According to the illustrated embodiment, the summary information button **524** may indicate that information depicted at density graph **504** corresponds to the particular use case of "No. 10578". By way of non-limiting example, this particular use case "No. 10578" may corresponding to use of the instrument **106** in a surgical operation. In this regard, one or more parameters may be indicated in relation to the characteristics of this particular use case. For example, the use case No.

10578 may correspond to a "high" risk profile (as shown in risk profile field **528**), for drilling through a "bone" material (as shown in the material field **530**), during a procedure indicated as an "urgent" criticality (as shown in the criticality field **532**). Notably, the information indicated at the foregoing fields may prompt the user, in conjunction with additional information displayed at instrument monitoring report **502**, to take one or more corrective actions. For example, the indication at risk profile field **528** may prompt the user to operate the instrument **106** in a manner consistent with a corresponding use case.

[0100] Additionally, the instrument monitoring report **502** may be configured to provide information in relation to the working tool **102** associated with the particular use case for which the density graph **504** depicts the instrument operating condition. In this regard, the instrument monitoring report may include working tool button **534** configured for manipulation by a user to cause information to be displayed in relation to the received working tool **102**. The working tool button **534** may include status tab **536** and inventory tab **538**. The status tab **536** may be manipulated by a user such that the instrument monitoring repot **502** displays information in relation to the characteristics or parameter values of the working tool **102** used in the instant use case corresponding to that depicted at the density graph **504**. For example, manipulation of the status tab **536** may cause information to be presented in relation to a working tool size, a working tool material, a working tool weight, a working tool manufacturer, a working tool serial number, and/or any other characteristics of interest associated with the received working tool **102**. Relatedly, the inventory tab **538** may be manipulated by a user to cause information associated with an inventory-dependent status corresponding to the subset of working tools **102** that share at least some of the same attributes of the received working tool **102** of the instant use case. For example, manipulation of the inventory tab **538** may cause working tool report **402** to display information at the inventory level graph **404** that corresponds to the subset of the plurality of working tools **102** that share the same characteristics of the received working tool **102** of the instant use case. This may be desirable, for example, in order to indicate a quantity of the plurality of remaining working tools **102** that remain available for associable use for an analogous subsequent use case or may be useful in cases where multiple working tools **102** are required to complete a single use case, etc.

[0101] To further facilitate the reader's understanding of the various functionalities of the utilities disclosed herein, reference is now made to flow diagram of FIG. **6**, which illustrates method **600** for use in monitoring an instrument. While specific steps and orders of steps of method **600** have been illustrated and will be discussed, other methods (including more, fewer, or different steps than those illustrates) consistent with the teaching presented herein are also envisioned and encompassed with the present disclosure.

[0102] In this regard, with reference to FIG. **6**, method **600** generally relates to a method for monitoring an instrument, for example, when receiving a working tool associated with one or more working tool attributes. In this regard, the method **600** may be initiated by engaging **602** a working tool with an instrument. For example, a working tool may be engaged with the instrument by advancing it into a receiving portion of the instrument. The engaged working tool may include a machine readable indicium indicative of a working tool attribute. As such, the various characteristics or parameters values that describe features associated with the particular engaged working tool may be embodied as a working tool attribute stored at the working tool itself via the attached machine readable indicium or retrievable in association therewith.

[0103] The method **600** may also include receiving **604**, based on the engaging, a working tool attribute. For example, an identifier may be received at a corresponding machine readable indicia reader. In this regard, the various characteristics or parameters values that describe features associated with the particular engaged working tool may be read from or otherwise transferred from the machine readable indicium of the engaged working tool. The method **600** may further include operating **606** a displacement measuring apparatus operatively associated with the instrument. In some instances, the displacement measuring apparatus may be disposed in

corresponding relation to the working tool to measure displacement of the working tool relative to an axis along which the working tool is advanced during use. In other instances, the displacement measuring apparatus may be embodied by various other sensors of the instrument that measure data for use in determining one or more operating conditions of the instrument.

[0104] The method **600** may further include providing **608** an output responsive to the received identifier. In this regard, the instrument **106** may be disposed remote from a controller or other communications and/or display device configured to indicate information in relation to the instrument.

[0105] As noted above, the foregoing functionality and system for monitoring an instrument with a working tool engaged thereby may be embodied by any number of instruments and corresponding working tools. According to one embodiment, the instrument **106** may be embodied by a drill that includes a drill bit penetration measuring system for determining, with respect to a reference point, a depth of penetration of a leading edge of a drill bit in a bore. In turn, the working tool **102** may be embodied by a drill bit that may be disposed for engagement with a chuck of the drill. In this regard, the drill bit may include a machine readable indicium indicative of a drill bit attribute such that the drill may receive an identifier of the drill bit at a corresponding machine readable indicia reader upon the receipt of the drill bit by the drill. As such, the foregoing disclosed functionalities of the system **100** may be configured for use with such drill and corresponding drill bit and accompanying measurement systems, according to embodiments described below.

[0106] As may be appreciated, certain aspects of the present disclosure may involve storage and manipulation of data in a database structure (e.g., to maintain information regarding specific working tools, operations, uses, etc.). It is presently contemplated that at least portions of such data may be advantageously provided in connection with a decentralized cryptographic distributed ledger such as blockchain. In this regard, blockchain technology may be used to capture and store data that is described herein. For instance, any data described herein may be provisioned in a blockchain such that transactions involving certain working tools may be stored and accessible for later review. Furthermore, use of blockchain technology may allow for leveraging of features facilitated by blockchain technologies such as smart contracts or the like. For instance, upon use of a working tool, the expenditure of the working tool may be noted in the blockchain, which may trigger reorder of a further working tool for a facility. Alternatively, if a supply level of working tools drops to a predetermined level, a smart contract built into the blockchain may be triggered to reorder working tools. Further still, certain information (e.g., provided via a hospital information system (HIS)) may be monitored and working tools may be automatically ordered in advance of a procedure. Such ordering may be facilitated using a blockchain. In this regard, the blockchain may be a public or private register. For instance, if information containing personally identifying information is provided, the blockchain may be private such that such information may be maintained in confidence.

[0107] In this regard, turning next to FIGS. **7-18**, where like numerals indicate like elements throughout, there is shown another embodiment of the system for monitoring an instrument with a working tool engaged thereby in relation to a drill bit penetration measurement system generally designated **700**, and hereinafter referred to as the "measurement system" **700**, in accordance with the present invention. The measurement system **700** is for determining, with respect to a reference point (not shown), a depth of penetration of a leading edge **702***a* of a rotating drill bit **702** in a bore when the leading edge **702***a* of the drill bit **702** passes from a first medium having a first density to a second medium adjacent the first medium and having a second density. The drill bit **702** is rotatably driven by a drive **704** in a drill housing **706** of any typical well known surgical drill. In this regard and as may be appreciated below, a measurement system **700** may be provided with an existing surgical drill as a retrofit. In a further embodiment described in greater detail below, a measurement system **1000** may be provided that is at least partially integrated into a drill **1002** as shown, for example, in FIGS. **16**A-**16**C.

[0108] Preferably the first and second media are a hard outer cortex **802** and a medium such as air or other anatomical structure (not shown) surrounding the outer surface of the cortical bone **804** and the bore is either a bicortical bore **806** or a unicortical bore **808** being drilled in the cortical bone **804** (See FIGS. **8**A-**8**B). However, those skilled in the art will understand from the present disclosure that the first and second media can be the hard outer cortex **802** and the soft inner medullary layer **809** of the cortical bone **804** or any adjacent media of different density without departing from the scope of the invention. The artisan will also understand that the reference point is a fixed point relative to which the displacement of the leading edge **702***a* of the drill bit **702** is measured and may correspond to an initial position of the measurement system **700** or portion thereof as further discussed below.

[0109] For example, as shown in FIGS. **8**A and **8**B, the bony structure of the human anatomy consists mainly of cortical bone **804**, including hard outer cortex **802** and soft inner medullary layer **809**. Following traumatic injury, plate and screw placement is critical for adequate repair of a fractured bone. Improper drilling lengths could lead to device instability, damage to anatomic structures, or device failure.

[0110] As shown in FIG. **8**A, when using the rotating drill bit **702** to form a bicortical bore **806** through the cortical bone **804**, the rotating drill bit **702** passes through a first portion **802***a* of the hard outer cortex **802**, a soft non-resistant medullary layer **809**, and a second portion **802***b* of the hard outer cortex **802**.

[0111] As shown in FIG. **8**B, when using the rotating drill bit **702** to form the unicortical bore **808** through the cortical bone **804**, the rotating drill bit **702** passes through an entry point **810***a* of the hard outer cortex **802** and an exit point **810***b* of the hard outer cortex **802** without penetrating the soft non-resistant medullary layer **809**. As such, with reference to FIG. **2**, the measurement system **700** comprises a drill bit displacement measurement assembly **708**, a drill bit load measurement assembly **710**, and a controller assembly **712**. The displacement measurement assembly **708** is connected to the drill housing **706**. The connection can be made by a variety of well-known mounting methods such as a mount that clamps to the displacement measurement assembly **708** and is attached to the drill housing **706** by one or more threaded fasteners. Alternative methods such as welding or adhesive bonding could also be used. The displacement measurement assembly **708** has a first sensor **714** that outputs a first signal **714***s* representative of a displacement, with respect to the reference point, of the leading edge **702***a* of the drill bit **702** in the bore being drilled. The displacement measurement assembly **708** preferably has an extension **716** that is displaceable along a longitudinal axis. The extension **716** has a distal end **716***a* that can be placed in registry with the reference point when the leading edge **702***a* of the drill bit **702** is positioned at the entry point, such as the entry point **806***a* of the bicortical bore **806** or the entry point **810***a* of the unicortical bore **808** shown in FIGS. **80**A-**8**B and maintained in registry with the reference point throughout the drilling process. The reference point can be any anatomical structure proximal to the desired location of the bore to be drilled. The extension **716** has a proximal end **716***b* that is attached to the first sensor **708**. Preferably the sensor **708** is a linear variable differential displacement transducer ("LVDT").

[0112] Referring to FIGS. **9**A and **9**B, the drill bit load measurement assembly **710** comprises a housing **718**, a thrust assembly **720** about which the housing **718** is rotatable, a drill chuck **722** and a second sensor **724**. The housing **718** has an axis of rotation **726** and is removably connected to the drive **704** for rotation thereby. Preferably, the housing **718** has a generally cylindrical-like shape and has a chamber **728** extending the length thereof for containing a portion of the thrust assembly **720** and a portion of the drill chuck **722**. Preferably, but not necessarily, the housing **718** also has a proximal end **718***a* with an outer diameter sized for being secured in a drive chuck **730** of the drive **704**. Those skilled in the art will understand from this disclosure that the drive chuck **730** can be any well-known surgical drill chuck through which surgical instruments are insertable.

[0113] The thrust assembly **720** is preferably a tube **732** with a bore **734** therethrough. The bore

734 has a piston **736** moveable therein. The tube **732** has a first portion **732***a* having a first outer diameter and a second portion **132***b* having a second outer diameter less than the first outer diameter. Similarly, the bore **734** has a first portion **734***a* having a first inner diameter and a second portion **734***b* having a second inner diameter less than the first inner diameter. Preferably, the piston **736** is in the first portion **734***a* of the bore **734**. The second portion **132***b* of the tube **732** extends beyond the proximal end **718***a* of the housing **718**. The thrust assembly **720** is connected to the housing **718** by a first bearing **738** and to the drill chuck **722** by a second bearing **740**, preferably connected to the piston **736**. Preferably, the first and second bearings **738**, **740** are thrust bearings suitable for use in a surgical environment. Alternatively, the first and second bearings **738**, **740** could be any device that permits the housing **718** and the drill chuck **722** to rotate with respect to the thrust assembly **720** and allows a force applied to the leading edge **702***a* of the drill bit **702** to be transferred to the thrust assembly **720**. Preferably, but not necessarily, the thrust assembly **720** also is journaled with the housing **718** by a third bearing **742**.

[0114] The drill chuck **722** is connected to the housing **718** for rotation therewith and to the thrust assembly **720** for rotation with respect thereto. The drill chuck **722** is moveable in translation along the axis of rotation **726** of the housing **718**. Preferably, the drill chuck **722** is a conventional surgical drill chuck having a proximal end **722***a* within the chamber **728** of the housing **718**. The drill chuck is connected to the housing **718** by a tab **744** extending radially outwardly from the proximal end **722***a* of the drill chuck **722**. The tab **744** extends into a corresponding slot **746** (FIG. **9**B) in the housing and is moveable therein in translation along the axis of rotation **726** of the housing **718**. Preferably, but not necessarily, the drill chuck **722** has diametrically opposed tabs **744**. Those of ordinary skill in the art will understand from the present disclosure that tabs **744** can be removably attached to the drill chuck **722** by a threaded fastener (not shown) to facilitate insertion of the proximal end **722***a* of the drill chuck into the housing **718**. The proximal end **722***a* of the drill chuck **722** additionally has a projection **748** that extends into the bore **734** of the thrust assembly **720** and is connected by the second bearing **740** to the piston of the thrust assembly **720**.

[0115] The second sensor **724** is connected to the thrust assembly **720** and outputs a second signal **724***s* representative of a force applied to the leading edge **702***a* of the drill bit **702**. As shown in FIG. **9**A, in one preferred embodiment of the present invention, the second sensor **724** is a hydraulic pressure transducer and a portion of the bore **734** forms a hydraulic chamber **750** connecting the second sensor **724** with the piston **736**. As shown in FIG. **10**A, in another preferred embodiment of the present invention, the second sensor **724′** is a load cell, such as a piezo-electric device, adjacent the piston **736** and a portion of the bore **734** forms a conduit **750′** through which passes an electrical conductor **752** connecting the piezo-electric device to the controller assembly **712**.

[0116] Referring to FIGS. **7** and **11**-**12**, the controller assembly **712** is in electrical communication with the first sensor **714** and the second sensor **724**. In an embodiment, the controller assembly **712** has a controller housing **754** integral with the drill housing **706**. However, with further reference to FIG. **15**A, the controller housing **754** may also be provided as a remote unit. The controller assembly **712** includes a processor **756** in electrical communication with the first and second sensors **714**, **724** and with a mode selector **758** having a mode selector switch **760** and a display **762** having a reset button **761**. The display **762**, the reset button **761** and the mode selector switch **760** may be mounted in a panel **764** of the controller housing **754**. Alternatively, the display **762** or the reset button **761** or the mode selector **760** or any combination thereof could be separately housed in the remote control unit that communicates with the first and second sensors **714**, **724** by a wired or wireless link. The display **762** is for indicating the measured displacement of the leading edge **702***a* of the drill bit **702** to the user. The display **762** is controlled by the processor **756**. The display **762** may continuously indicate the changing displacement of the leading edge **702***a* of the drill bit **702** during the drilling of a bore and may also indicate the length of the bore at the when the drill bit **702** passes from one medium to another. In another embodiment, the remote unit may

include a remote controller operable to provide an output indicative of a drill bit operating condition, as discussed in greater detail below.

[0117] For instance, with continued reference to FIGS. **15**A and **15**B, the display **762** may be a touch sensitive display. The display **762** may include an indication of a bore diameter **766**, the drill speed **768**, a drill direction **770**, and a screw size indicator **772**. The display **762** may also include patient information **774**. The controller assembly **712** may include a port **776** for engagement of a wired plug connection **778** with the drill **1002**. In other embodiments, the drill **1002** may include a wireless connection to facilitate the foregoing. In this regard, the drill **1002** may be connected to the controller assembly **712** to supply power to the drill **1002** and communicate data between the drill **1002** and the controller assembly **712**.

[0118] Referring to FIGS. **7**, **11-12**, **13**A, **13**B, and **13**C, the processor **756** is configured to operate in a first mode for drill bit penetration measurement in unicortical bore drilling. In the first mode the processor **756** is configured to output a third signal **756**$s1$ representative of the depth of penetration of the leading edge **702**a of the drill bit **702** when the leading edge **702**a of the drill bit **702** passes from the first medium to the second medium. The third signal **756**$s1$ is based on the first and second signals **714**s, **724**s. Preferably, the third signal **756**$s1$ is output upon a first occurrence **780** of a second time derivative of the first signal **714**s being greater than zero and a first time derivative of the second signal **724**s being less than zero. In other words, a positive acceleration of the drill bit **702** and a concurrent reduction in the force applies to the leading edge **702**a of the drill bit **702** trigger the first occurrence **780**. At the time of the first occurrence **780**, the third signal **756**$s1$ corresponds to the length of the unicortical drill path.

[0119] Preferably, but not necessarily, the processor **756** is also configured to operate in a second mode for drill bit penetration measurement in bicortical bore drilling and the mode selector **758** and mode selector switch **760** are for selecting between the first and second modes. The second mode of operation is directed to the case where the first medium is the cortical bone **802** surrounded by a second medium, such as the air or tissue surrounding the outer surface of the cortical bone **802**, and the first medium encloses a third medium, such as the soft medullary layer **809**, having a third density. In the second mode, the processor **756** is configured to output the third signal **756**$s2$ in response to a second occurrence **782** of the second time derivative of the first signal **714**s being greater than zero and the first time derivative of the second signal **724**s being less than zero and corresponds to the length of the bicortical drill path. Accordingly, the third signal **756**$s2$ is output after the second time the drill bit **702** accelerates with a concurrent reduction in the force applied to the leading edge **702**a of the drill bit **702**.

[0120] Additionally or alternatively, the third signal **756**s (collectively referring to **756**$s1$ and **756**$s2$ referenced above) may be at least partially based on additional parameters other than the first signal **714**s and second signal **724**s. For instance, in at least some embodiments, the third signal **756**s may be at least partially based on a parameter associated with the rotation of the drill bit **702**. For instance, the speed of the drive **704** turning the drill bit **702**, the torque applied to the drill bit **702** by the drive **704**, or another appropriate parameter regarding the rotation of the bit **702** may be utilized in outputting the third signal **756**s. Further still, parameters such as the diameter of the drill bit **702**, the bone to be drilled, or other appropriate parameters may be utilized in determining the third signal **756**s.

[0121] Furthermore, the generation of the third signal **756**s may at least partially be customized based on the patient. In this regard, information regarding the patient may be provided to the controller assembly **712** and utilized by the processor **756** in determining the third signal **756**s. For instance, a patient's age, sex, and/or other demographic information may be provided. As may be appreciated, the demographic data of the patient may provide a correlation to expected bone density or other parameter regarding an expected property of the patient's anatomy based on the demographic data of the patient. In this regard, the demographic data may be used to correlate an expected parameter associated with the patient's anatomy (e.g., bone density) that may be used as a

factor in generation of the third signal **756***s*. In addition, direct measurement of an anatomical parameter for a given patient may be provided directly to the controller assembly **712**, thereby potentially eliminating the need to estimate the parameter based on demographic data.

[0122] Referring to FIG. **14**, there is shown a block diagram of a first preferred method for determining, with respect to a reference point, the depth of penetration of the leading edge **702***a* of a rotating drill bit **702** in a bore when the leading edge **702***a* of the drill bit **702** transitions from a first medium having a first density, such as the hard outer cortex **802** of a cortical bone **804**, to a second adjacent medium having a second density, such air or tissue surrounding the outer surface of the cortical bone **804** (FIG. **8**B).

[0123] An initial position of the leading edge **702***a* of the drill bit **702** relative to the reference point is established (Step **1405**). The initial position may be established by placing the leading edge **702***a* of the drill bit **702** against the outer surface of the cortical bone to be drilled and by extending the distal end **716***a* of the extension **716** of the displacement measurement assembly **708** to the reference point, such as an anatomical structure proximal to the desired location of the bore to be drilled. As will be appreciated in the discussion of the embodiments below, the reference point may also be established by a bushing member of a drill bit assembly that is engaged with a displacement sensing arm of a displacement sensor. With the leading edge **702***a* of the drill bit **702** and the measurement system reference point in the above positions (i.e., aligned at a surface of the medium to be drilled), the measured displacement of the drill bit **702** is set to zero by pressing the reset button **761**. Upon commencement of drilling, a first signal representing the depth of penetration of the leading edge **702***a* of the rotating drill bit **702** in the bore is output (Step **1410**). A second signal representing a force applied to the leading edge of the drill bit is output (Step **1415**). A third signal based on the first and second signals and representative of the depth of penetration of the leading edge of the drill bit when the leading edge of the drill bit passes from the first medium to the second medium is output (Step **1420**). Preferably, the third signal is output when the second time derivative of the first signal is greater than zero and a first time derivative of the second signal is less than zero.

[0124] The third signal may be accompanied by an alert that may be perceivable by a user of the drill. As such, upon determination that the drill has passed through the bone, the alert may provide feedback to the user that the bone has been drilled through. As such, the alert may be an auditory alert such as a tone or the like. In another embodiment, the alert may be a change in the speed of the motor of the drill. For instance, the drill may be slowed such that the user may be alerted to the fact that the drill has passed through the bone. Further still, the drill may be stopped at the occurrence of the third signal. It may be appreciated that any other user perceivable alert may be provided including, for example, a visual, tactic, or other type of user perceivable feedback.

[0125] Notably, the components used to construct the present invention may consist of a variety of materials that are customarily used in the manufacture of surgical drills. One having ordinary skill in the art will readily appreciate the materials that most desirably may be used to construct the present invention. In a preferred embodiment, however, the drilling mechanism, drill bit displacement measurement assembly, the drill bit load measurement assembly and the structural elements of the controller assembly may be constructed of a combination of polymeric materials, polymers, and stainless steel.

[0126] Furthermore, it may be appreciated that the spacing of the extension **716** of the displacement sensor **708** from the drill bit **702** may introduce the potential for errors or other disadvantages in determining the displacement of the drill bit **702** relative to the reference point. For instance, as the extension **716** may contact a structure that is offset from the contact point between the leading edge **702***a* of the drill bit **702** and the medium to be drilled. Accordingly, any movement between the structure contacted by the extension **716** and the medium to be drilled may be falsely registered as relative movement of the drill bit **702** with respect to the reference point. Furthermore, there may not be a rigid structure to contact adjacent to the medium to be drilled,

leading to displacement of the structure contacted by the extension **716** such as in the case where the extension **716** may contact soft tissue adjacent to the medium to be drilled given the offset from the location to be drilled. Furthermore, the offset nature of the extension **716** relative to the contact between the drill bit **702** and the medium to be drilled may lead to other complications such as having to expose a greater surface of the medium to be drilled, which may adversely affect patient outcomes.

[0127] As such, an improved embodiment of a drill with an improved displacement sensor including a displacement sensing arm that extends from the drill may be provided. For example, such a displacement sensing arm may be provided that may coordinate with a bushing member of a drill bit assembly that may be used with the drill. In this regard, the bushing may move along the drill bit in a direction corresponding to the axis of rotation of the drill bit. Upon engagement of the bushing and the displacement sensing arm, the bushing and displacement sensing arm may undergo corresponding movement. As such, the bushing may be disposed in contact with the medium to be drilled when the leading edge of the drill bit is in contact with the medium. As such, a reference point may be established when the bushing and leading edge of the drill bit are both in contact with the medium to be drilled. As the bushing is located adjacent to (e.g., partially or fully surrounding) the drill bit, the bushing may facilitate contact with the medium at or very near the location to be drilled prior to creating a bore as described above. In this regard, the reference point may be more accurately maintained as the bushing may contact at least a portion of a periphery of the bore created in the medium drilled. That is, the bushing may remain in intimate contact with the medium to be drilled adjacent to the bore created. This may prevent false displacement readings attributable to the foregoing problems associated with an offset extension **716**. Furthermore, the amount of contact of the drill may be localized at the location to be drilled, thus allowing for potentially less intrusion when performing drilling operations.

[0128] For example, with additional reference to FIGS. **16**A-**16**C and **17**, an embodiment of a drill **1002** comprising an embodiment of a measurement system **1000** is shown. The drill **1002** may be adapted for use with a drill bit assembly **1004** that may include a bushing **1006**. The drill **1002** may integrally comprise at least some components of the measurement system **1000** to facilitate operation of the measurement system **1000** in connection with the drill **1002**. For example, at least a portion of a displacement sensor **1008** may be integrated into a housing **706** of the drill **1002**. In this regard, the displacement sensor **1008** may include a depth sensing arm **1010** that is specifically adapted for engagement with a bushing **1006** of a drill bit assembly **1004** that may be engaged by a chuck **1014** of the drill **1002**.

[0129] In this regard, the depth sensing arm **1010** may be used to establish a reference point from which displacement of the drill bit **702** may be measured as described above. In this regard, as follows herein, a general description of the features and operation of the drill **1002** used in conjunction with the drill bit assembly **1004** is provided.

[0130] As may be appreciated in FIGS. **16**A-**16**C, the displacement sensor **1008** may include a depth sensing arm **1010** that may extend from the drill housing **706**. For example, the depth sensing arm **1010** may extend distally (e.g., from a distal face **1016** of the drill housing **706**) in a direction corresponding with the direction in which the drill bit **702** extends from a chuck **1014** of the drill **1002**. At least a portion of the displacement sensing arm **1010** may extend from the drill housing **706** parallel to an axis of rotation **726** of the drill **1002**. The depth sensing arm **1010** may also include a distal portion **1018** that is adapted to engage the bushing **1006** provided with the drill bit assembly **1004**. As used herein, distal may correspond to a direction from the drill **1002** toward the leading edge **702***a* of the drill bit **702** and proximal may correspond to a direction from the leading edge **702***a* of the drill bit **702** toward the drill **1002**. In this regard, at least a portion of the depth sensing arm **1010** (e.g., the distal portion **1018**) may be adapted to engage the bushing **1006** of the drill bit assembly **1004** as will be described in more detail below. In any regard, at least a portion of the depth sensing arm **1010** may extend into the housing **706**. With further reference to FIG. **17**, the

housing **706** may contain a coil **1020**. As such, a proximal end **1022** of the displacement sensing arm **1010** may interface with the coil **1020** of the displacement sensor **1008** that may be disposed within the drill housing **706**.

[0131] Specifically, in FIG. **17**, the depth sensing arm **1010** is shown in a retracted position relative to the drill bit **702**. As such, this retracted position shown in FIG. **17** may occur when the drill bit **702** is advanced relative to the bushing **1006** during drilling. In this regard, the proximal end **1022** of the displacement sensing arm **1010** is disposed within the coil **1020** of the displacement sensor **1008**. Accordingly, the displacement sensor **1008** may comprise an LVDT sensor as described above that is adapted to sense the position of a core **1024** relative to the coil **1020**. The displacement sensing arm **1010** may incorporate the core **1024** at the proximal end **1022** thereof. Accordingly, as the proximal end **1022** of the displacement sensing arm **1010** is moved relative to the coil **1020**, the location of the core **1024** may be determined to provide an output corresponding to the position of the core **1024**, and in turn the displacement sensing arm **1010** relative to the drill housing **706**. That is, the depth sensing arm **1010** may be displaceable relative to the coil **1020** such that the displacement sensor **1008** may be operable to sense a change in position of the depth sensing arm **1010** relative to the drill housing **706** and output a measure of the displacement that may be used as described above in determining a depth of a bore. In an embodiment, the total measurable travel of the core **1024** relative to the coil **1020** may be at least about 2.5 in (6.4 cm). Furthermore, the resolution of the output of the displacement sensor **1008** may be about 0.1% (e.g., about 0.002 inches (0.06 mm) for a sensor having a total measureable travel of 2.5 inches).

[0132] While a LVDT displacement sensor is shown and described in relation to the drill **1002** shown in the accompanying figures, it may be appreciated that other types of displacement sensors may be provided. For instance, the sensor may provide for the absolute or relative measurement of the position of the distal end of the displacement sensing arm **1010** to provide a displacement measure. For instance, in another embodiment, an optical displacement sensor may be provided. Other types of displacement sensors are also contemplated such as, for example, a capacitive displacement sensor, ultrasonic sensors, Hall effect sensors, or any other sensors known in the art capable of outputting an absolute or relative position measure.

[0133] In an embodiment, the coil **1020** may define a passage **1026** extending at least partially through the housing **706**. Specifically, the passage **1026** may extend from a proximal face **1028** of the housing **706** to the distal face **1016** of the housing **706**. That is, the passage **1026** may extend entirely though the housing **706**. An end cap **1030** may be provided that is operable to close the proximal end of the passage **1026** at the proximal face **1028** of the drill housing **706**. Furthermore, a biasing member **1032** (e.g., a coil spring) may be provided in the passageway **1026** at a proximal end thereof. The biasing member **1032** may be provided between the end cap **1030** and the proximal end **1022** of the displacement sensing arm **1010**. In this regard, the biasing member **1032** may act on the proximal end **1022** of the displacement sensing arm **1010** to bias the displacement sensing arm **1010** distally relative to the passage **1026** and drill housing **706**.

[0134] As such, the displacement sensing arm **1010** may include features that selectively prevent ejection of the displacement sensing arm **1010** from the distal end of the passage **1026**. For example, the displacement sensing arm **1010** may include at least one flat **1034** that extends along a portion of the arm **1010**. At the proximal and distal extents of the flat **1034**, the displacement sensing arm **1010** may include shoulders **1036** that project from the flats **1034** (best seen at the distal portion **1018** in FIG. **16**B and at the proximal end portion **1022** in FIG. **17**). As such, at the proximal opening of the passage **1026**, a selectively displaceable stop **1038** may be disposed relative to the flat **1034** such that the flat **1034** may move relative to the stop **1038**, but interfere with the shoulder **1036** defined in the displacement sensing arm **1010** to prevent passage of the shoulder **1036** beyond the stop **1038**. In this regard, the length of the displacement sensing arm **1010** along which the flat **1034** extends may be moveable relative to the stop **1038**, and the stop **1038** may limit proximal and distal movement of the displacement sensing arm **1010** beyond the

stop **1038**.

[0135] However, the stop **1038** may be displaceable upon depressing, for example, a button **1040** provided on an exterior of the housing **706**. Thus, upon depressing the button **1040**, the stop **1038** may be displaced away from the displacement sensing arm **1010** to allow the shoulder **1036** to pass distally from the distal end of the passage **1026** such that the displacement sensing arm **1010** may be removed entirely from the passage **1026**. The distal end of the flats **1038** may include a detent **1042** that may be engageable with the stop **1038** so as to maintain the displacement sensing arm **1010** in a proximally disposed, retracted position relative to the housing (e.g., as shown in FIG. **17**). Once the button **1040** is depressed and released, the detent **1042** at the proximal end of the flat **1034** of the displacement sensing arm **1010** may be released by the stop **1038** and the displacement sensing arm **1010** may move proximally (e.g., under influence of the biasing member **1032**). The displacement sensing arm **1010** may move proximally until the shoulder **1036** at the distal end of the flat **1034** are engaged to prevent further distal movement of the displacement sensing arm **1010**. Accordingly, the displacement sensing arm **1010** may be retained in a retracted position, released to be moveable relative to and biased proximally with respect to the housing **706**, and removable altogether from the housing **706**.

[0136] In the latter regard, removal of the displacement sensing arm **1010** and biasing member **1032** from the passage **1026** may allow for separate cleaning of those members. Additionally, removal of the end cap **1030** may allow for a cleaning apparatus to be passed through the full length of the passage **1026** to facilitate cleaning thereof.

[0137] As referenced above, the distal portion **1018** of the displacement sensing arm **1010** may be adapted to engage a drill bit assembly **1004** that is correspondingly adapted for use with the drill **1002**. For instance, as shown in FIGS. **16**A-**16**C and FIG. **17**, the displacement sensing arm **1010** may generally be linear along the proximal portion **1022** of the displacement sensing arm **1010**. In this regard, the proximal portion **1022** may be adapted to be collinear with the passage **1026** and moveable within the passage **1026**. Furthermore, the distal portion **1018** of the displacement sensing arm **1010** (e.g., the portion distal to the linear portion of the displacement sensing arm **1010**) may extend from the linear portion of the displacement sensing arm **1010** toward the drill bit assembly **1004** that may be engaged by the chuck **1014** of the drill **1002**. In this regard, the linear portion of the displacement sensing arm **1010** may be substantially parallel to and offset from the axis of rotation **726**. The distal portion **1018** may extend from the linear portion in a direction corresponding with the offset such that the distal portion **1018** extends toward the drill bit assembly **1004**. This may facilitate engagement between the displacement sensing arm **1010** and the bushing **1006** of the drill bit assembly **1004**. As shown, in FIGS. **16**A-**16**C and **17**, the distal portion **1018** may be an at least partially arcuate member extending along a radius of curvature toward the drill bit assembly **1004**. However, the distal portion **1018** may be shaped differently (e.g., the distal portion **1018** may be a linear portion extending at an angle or perpendicularly from the proximal **1022** toward the drill bit assembly **1004**).

[0138] For instance, with further reference to FIG. **18**, a schematic section view of a drill bit **702** that has been advanced into a medium **1100** is shown. The bushing **1006** may be disposed about the drill bit **702**. As such, the bushing **1006** may be disposed about the periphery of a bore **1102** created upon advancement of the drill bit **702** into the medium **1100**. That is, the bushing **1006** may remain in contact with the surface **1102** of the medium **1100** upon advancement of the drill bit **702** into the medium **1100**. In this regard, the bushing **1006** may include a reference surface **1104** at a distal portion thereof. The reference surface **1104** may contact the surface **1102** of the medium **1100** to be drilled. As such, prior to initiation of the drilling when the leading edge **702***a* of the drill bit **702** is also in contact with the surface **1102**, the displacement sensor **1008** may be set to establish the reference point. Accordingly, as the drill bit **702** is advanced, the reference surface **1104** may remain in contact with the surface **1102** of the medium **1100**. The reference surface **1104** may contact the surface **1102** about a periphery of a bore **1106**. In an embodiment, the reference surface

1104 may extend circumferentially about a majority or substantially all of the drill bit **702** such that the reference surface **1104** may also extend circumferentially about a majority of or substantially all of the periphery of the bore **1106**. The distally biased displacement sensing arm **1010** may act on the bushing **1006** (e.g., by way of post **1044** received in hole **1048**) to maintain the bushing **1006** in contact with the surface **1102**. In any regard, the displacement (d) of the leading edge **702***a* of the drill bit **702** relative to the reference surface **1104** of the bushing **1006** may be measured upon corresponding movement of the core **1024** at the proximal end **1022** of the displacement sensing arm **1010** relative to the coil **1020**.

[0139] The foregoing description of the present invention has been presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, and skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments described hereinabove are further intended to explain best modes known of practicing the invention and to enable others skilled in the art to utilize the invention in such, or other embodiments and with various modifications required by the particular application(s) or use(s) of the present invention. It is intended that the appended claims be construed to include alternative embodiments to the extent permitted by the prior art.

Claims

1-42. (canceled)

43. A method for monitoring an instrument, the method comprising: engaging a working tool with an instrument, the working tool including a machine readable indicium indicative of a working tool attribute; receiving, based on the engaging, an identifier of the working tool at a corresponding machine-readable indicia reader; operating a displacement measuring apparatus operatively associated with the instrument and disposed in corresponding relation to the working tool to measure displacement of the working tool relative to an axis along which the working tool is advanced during use; and providing an output responsive to the received identifier of the working tool.

44. The method of claim 43, wherein the machine readable indicium includes a radio frequency identification (RFID) tag.

45. The method of claim 43, wherein the corresponding machine readable indicia reader includes a radio frequency identification (RFID) reader.

46. The method of claim 43, wherein the received identifier of the working tool is indicative of receipt of the working tool by the instrument.

47. The method of claim 43, wherein the working tool attribute comprises at least one of a working tool size, a working tool material, a working tool manufacturer, and a working tool serial number.

48. The method of claim 43, further comprising: identifying an instrument operating condition via a data collection module operatively associated with the displacement measuring apparatus, the data collection module including a processor for obtaining the measured displacement of the working tool and identifying the instrument operating condition; and providing an output responsive to identification of the instrument operating condition.

49. The method of claim 48, wherein the instrument operating condition is at least partially based on the working tool attribute.

50. The method of claim 43, further comprising: transmitting the provided output to a remote controller in operative communication with the instrument.

51. The method of claim 50, wherein the transmitted output is transmitted via a wireless transmitter.

52. The method of claim 50, wherein the transmitted output is transmitted via a hardwired connection.

53. The method of claim 48, wherein the instrument operating condition is indicative of a condition-dependent status, the condition-dependent status corresponding to a physical condition of the instrument.

54. The method of claim 48, wherein the working tool is one of a plurality of working tools, each of the plurality of working tools receivable by the instrument, and wherein the instrument operating condition is indicative of an inventory-dependent status, the inventory dependent-status corresponding to receipt of the plurality of working tools with the instrument.

55. The method of claim 48, wherein the instrument is one of a plurality of instruments, each of the plurality of instruments in operative communication with a central processor remote from the plurality of instruments.

56. The method of claim 55, wherein the output responsive to the identification of the instrument operating condition is associated with a correlation factor, the correlation factor determined at the central processor at least partially based on an electronic signal received from at least one of the plurality of instruments, the electronic signal corresponding to a received identifier of a respective working tool associated with the at least one of the plurality of instruments.

57-70. (canceled)

71. A method for monitoring an instrument, the method comprising: engaging a working tool with a powered instrument, the working tool including a machine readable indicium indicative of an identifier of the working tool; reading the machine readable indicium using a machine-readable indicia reader; receiving, based on the reading, the identifier of the working tool at a processing engine of the powered instrument; looking up an attribute of the working tool based upon the identifier of the working tool in a database; and determining an operating status of the powered instrument based upon the attribute.

72. The method of claim 71, further comprising: associating, at a controller communicatively coupled to the powered instrument, an operation identification indicative of an operation for which the powered instrument is intended for use; and referencing the working tool identifier against at least one rule to determine the attribute, wherein the at least one rule is selected based upon the operation identification.

73. The method of claim 72, wherein the at least one rule comprises a condition specifying that the working tool identifier is not in a list of working tool identifiers associated with working tools that have been used in operations.

74. The method of claim 73, wherein the attribute indicates that the condition is satisfied and the operating status comprises allowing a drive motor of the powered instrument to operate.

75. The method of claim 71, wherein the attribute comprises an indication of manufacturer of the working tool.

76. The method of claim 71, wherein: the attribute comprises an indication of a manufacturer's maximum recommended operating speed; the operating status comprises a drive motor speed that is less than or equal to the manufacturer's maximum recommended operating speed; and the processing engine restricts operation of the drive motor according to an operating status.)