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System and method for detecting end gun status

Abstract

The present invention provides a system and method for using a small, wireless gyroscopic sensor to monitor end gun operations. Further, the present invention provides a system and method for using an accelerometer to detect vibrations at the end gun. According to further preferred embodiments, the present invention includes a diagnostic application which receives gyroscopic sensor data and accelerometer data. The diagnostic applications of the present invention preferably include logic and threshold limits which are applied to the received data. The present system preferably provides notifications and warnings based on detected changes in rotational motion, orientation changes and vibration levels in and around the end gun.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
7584023	12/2008	Palmer et al.	N/A	N/A
10561061	12/2019	Leeb	N/A	A01C 23/047
2012/0043395	12/2011	Hill	239/69	B05B 12/008
2013/0087640	12/2012	Pfrenger	239/723	A01G 25/092
2013/0226356	12/2012	Pfrenger et al.	N/A	N/A
2014/0277676	12/2013	Gattis et al.	N/A	N/A
2015/0226177	12/2014	DeFrank et al.	N/A	N/A
2016/0282219	12/2015	Kinoshita	N/A	G01M 3/24
2016/0330948	12/2015	Schnaider	N/A	A01M 7/0085
2019/0023313	12/2018	Zuzelski	N/A	B62D 5/0481
2020/0023395	12/2019	Tangen	N/A	B05B 12/006
2020/0154655	12/2019	Dick	N/A	A01G 25/092
2022/0030785	12/2021	Miller	N/A	H04Q 9/00

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
109101032	12/2022	CN	G01C 21/10

OTHER PUBLICATIONS

International Application PCT/US21/41356, International Search Report and Written Opinion mailed Oct. 20, 2021, 9 pages. cited by applicant

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Background/Summary

RELATED APPLICATIONS (1) The present application claims priority to U.S. Provisional Application No. 63/058,560 filed Jul. 30, 2020.

BACKGROUND AND FIELD OF THE PRESENT INVENTION
Field of the Present Invention
(1) The present invention relates generally to a system and method for monitoring aspects of a mechanized irrigation system. More particularly, the present invention provides a system and method for detecting and monitoring the position and status of an end gun.
Background of the Invention
(2) Modern center pivot and linear irrigation systems generally include interconnected spans (e.g., irrigation spans) supported by one or more tower structures to support the conduits (e.g., water pipe sections). In turn, the conduits are further attached to sprinkler/nozzle systems which spray water (or other applicants) in a desired pattern. Optionally, endguns may be attached to the end of any irrigation span to add further coverage. In use, endguns can greatly extend the reach and range of an irrigation system.
(3) End guns operate at a given trajectory and over specific angles (i.e. half circle, full circle). Commonly, endguns are heavy duty impact sprinklers which include controllable valves to control the flow rate of the endgun. They may also include pressure boosting systems to extend the range of the endgun.
(4) In present designs, end guns are independent from the detection and monitoring systems of the main irrigation system. Accordingly, end guns do not provide any feedback to the irrigation system, and operators must visually see the end gun during irrigation to assess whether the end gun is functioning properly. Wired systems and sensors have been used to monitor other elements of irrigation systems. However, these are difficult to use with end guns due to their distance from the main control panel and their continuous movement during irrigation. Further, transducers and simple water pressure measurements cannot provide a full assessment of how the end gun is functioning.
SUMMARY OF THE PRESENT INVENTION
(5) To address the shortcomings presented in the prior art, the present invention provides a system and method for using a small, wireless gyroscopic sensor to monitor end gun operations. Further, the present invention provides a system and method for using an accelerometer to detect vibrations at the end gun.
(6) According to further preferred embodiments, the present invention includes a diagnostic application which receives gyroscopic sensor data and accelerometer data. The diagnostic applications of the present invention preferably include logic and threshold limits which are applied to the received data. The present system preferably provides notifications and warnings based on detected changes in rotational motion, orientation changes and vibration levels in and around the end gun.
(7) The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate various embodiments of the present invention and together with the description serve to explain the principles of the present invention.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** shows an exemplary irrigation system for use with the present invention.
(2) FIG. **2** shows a block diagram illustrating an exemplary processing architecture of a control

device in accordance with a first preferred embodiment of the present invention.
(3) FIG. **3** shows a block diagram illustrating an exemplary system architecture in accordance with further aspects of the present invention.
(4) FIG. **4** shows an exemplary end gun configuration in accordance with a preferred embodiment of the present invention.
(5) FIG. **5** shows a flow chart illustrating an exemplary method in accordance with a first preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(6) For the purposes of promoting an understanding of the principles of the present invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the present invention is hereby intended and such alterations and further modifications in the illustrated devices are contemplated as would normally occur to one skilled in the art.
(7) The terms "program," "computer program," "software application," "module," firmware" and the like as used herein, are defined as a sequence of instructions designed for execution on a computer system. A program, computer program, module or software application may include a subroutine, a function, a procedure, an object implementation, an executable application, an applet, a servlet, a source code, an object code, a shared library, a dynamic load library and/or other sequence of instructions designed for execution on a computer system. A data storage means, as defined herein, includes many different types of computer readable media that allow a computer to read data therefrom and that maintain the data stored for the computer to be able to read the data again. Such data storage can include, for example, non-volatile memory (such as ROM) and volatile storage (such as RAM, buffers, cache memory, and network circuits).
(8) Aspects of the systems and methods described herein may be implemented as functionality programmed into any of a variety of circuitry, including programmable logic devices and controllers (PLDs/PLCs), such as field programmable gate arrays (FPGAs), programmable array logic (PAL) devices, electrically programmable logic and memory devices and standard cell-based devices, as well as application specific integrated circuits (ASICs). Some other possibilities for implementing aspects of the systems and methods includes: microcontrollers with memory, embedded microprocessors, firmware, software, etc. Furthermore, aspects of the systems and methods may be embodied in microprocessors having software-based circuit emulation, discrete logic (sequential and combinatorial), custom devices, fuzzy (neutral network) logic, quantum devices, and hybrids of any of the above device types.
(9) With reference now to FIG. **1**, an exemplary system **100** incorporating aspects of the present invention shall now be discussed. According to a preferred embodiment, an exemplary irrigation system **100** may include a first drive tower **102**, a last drive tower (LRDU) **104**, and a corner drive tower **106**. The drive towers **102**, **104**, **106** support connected spans **110** which carry water (or other applicants) to a variety of sprinklers **126** and to an end gun **132**. As shown, the system may also include pressure sensors and regulators (transducers) **120**, **122**, **124** which are provided to control and regulate water pressure to the sprinklers **126** and the end gun **132**. The end gun **132** may preferably include a sensor housing **134** which may include positional and vibrational sensors as discussed further below.
(10) As shown, the each drive tower **102**, **104**, **106** may include a tower box **112**, **114**, **116** which are preferably interconnected to respective drive unit motors **107**, **109**, **111**. Each tower box may include control boards, motor controllers, non-contact alignment devices and other components as further with respect to FIG. **3** below.
(11) As further shown, the respective drive unit motors **107**, **109**, **111** preferably provide torque and braking to respective sets of drive wheels. As discussed above, the system of the present invention may include any suitable motor for providing torque to a drive wheel. According to a preferred embodiment, the system of the present invention may preferably include motors such as switch

reluctance motors, induction motors and the like.

(12) Further, the system **100** of the present invention may preferably further include a control/pivot panel **108** as well as elements such as GPS receivers **118** for receiving positional data. Still further, a system of the present invention may further include indirect crop sensors **128** which preferably may include optional moisture sensors to determine the moisture levels in a given area of soil. Additional sensors **130** may further include optics to allow for the detection of crop type, stage of grown, health, presence of disease, rate of growth and the like. Still further, the system may include ground sensors. Still further, the detection system may further receive data from a connected or remote weather station or the like which is able to measure weather features such as humidity, wind speed, wind direction, pressure, precipitation, temperature and the like. Further, the preferred system of the present invention may alternatively further include additional elements mounted to the span **110** such as additional sensors and the like.

(13) With reference now to FIG. **2**, an exemplary control device **200** which represents functionality to control one or more operational aspects of the irrigation system **100** will now be discussed. As shown, an exemplary control device **200** preferably includes a processor **202**, a memory **206**, an irrigation position module **210** and a network interface **204**. The processor **202** provides processing functionality for the control device **200** and may include any number of processors, micro-controllers, or other processing systems. The processor **202** may execute one or more software programs that implement techniques described herein. The memory **206** is an example of tangible computer-readable media that provides storage functionality to store various data associated with the operation of the present invention, such as the software program and code segments mentioned above, or other data to instruct the processor **202** and other elements of the control device **200** to perform the steps described herein. The memory **206** may include, for example, removable and non-removable memory elements such as RAM, ROM, Flash (e.g., SD Card, mini-SD card, micro-SD Card), magnetic, optical, USB memory devices, and so forth. The network interface **204** provides functionality to enable the control device **200** to communicate with one or more networks **216** through a variety of components such as wireless access points, transceivers and so forth, and any associated software employed by these components (e.g., drivers, configuration software, and so on).

(14) In implementations, the irrigation position-determining module **210** may receive data from a global positioning system (GPS) receiver or the like to calculate the location of the irrigation system **100**. Further, the control device **200** may be coupled to a guidance device **218** or similar system of the irrigation system **100** (e.g., steering assembly or steering mechanism) to control movement of the irrigation system **100**. As shown, the control device **200** may also preferably include multiple inputs and outputs to receive data from sensors **216-224** and monitoring devices as discussed further below.

(15) The present invention may preferably also include an End Gun Pressure and Angle Adjustment Module **212** ("End Gun Module **212**"). The End Gun Module **212** is preferably linked to systems which monitor, control and adjust end gun settings/parameters. The End Gun Module **212** preferably may receive and store data from an end gun accelerometer **222** and gyroscopic **224**. According to preferred embodiments, the gyroscopic sensors **224** of the present invention may be any type of angular rate or angular velocity sensor. For example, the gyroscopic sensors **224** may be ring laser gyros, fiber-optic gyros or fluid gyros without limitation.

(16) The accelerometer **222** and gyroscope **224** sensors may preferably be coupled with a wired or wireless transceiver for transmitting detected data to the processor **202** and the End Gun Module **212**. In this way, the accelerometer **222** and gyroscope **224** sensors may preferably provide data for use with system diagnostics to determine the status and proper functioning of the end gun. According to an exemplary preferred embodiment, the End Gun Module **212** may use the received data to calculate oscillations within the span which may be parallel (forward/backwards rocking) or orthogonal (pushing/pulling within the span) to the direction of movement.

(17) Additionally, the End Gun Module **212** may also compare the accelerometer **222** data to stored profiles of acceptable vibration levels based on the speed of the irrigation span, the water pressure and other factors such as stored vibration thresholds linked to irrigation path data **208**. For example, the End Gun Module **212** may determine that a component of the end gun (i.e. the drive arm **404**) may not be functioning properly or that the water pressure is too low based on detected levels of vibrations within the end gun.

(18) The End Gun Module **212** may likewise compare the gyroscope **224** data with stored gyroscopic sensor data for irrigation plan thresholds for given time segments and water pressures (i.e., gyroscopic data profiles **214**). For example, the End Gun Module **212** may determine that the end gun is not functioning properly based on a detected rate of angular travel over a given time period at a given water pressure. Conversely, the End Gun Module **212** may calculate/detect water pressure based on a detected rate of angular travel.

(19) With reference now to FIG. **3**, an exemplary control system **300** in accordance with a preferred embodiment of the present invention shall now be discussed. As shown in FIG. **3**, the control/pivot panel box **302** of the present invention may preferably include a main pivot controller **304** which controls and directs signals and power to downstream tower boxes/units **308** via a signal/power bus **306** or the like. The tower boxes/units **308** may include components such as drive unit controllers **310**, GPS sensors **312** and drive motors **314**.

(20) According to a first preferred embodiment, the pivot panel box **302** may provide power and control signals through a pivot point PLC board via a power-line BUS. Alternatively, any other type of control and communication systems may also be used. For example, the signals of the present invention may be transmitted between system elements using any wireless (e.g. Wi-Fi, Zigbee) or wired protocol (e.g. PLC, ethernet). Further, the present invention is not intended to be limited to the use of solid-state tower boxes. For example, electro-mechanical tower boxes may be used with or without a PLC system without departing from the scope of the present invention.

(21) As further shown in FIG. **3**, the system may preferably further include an end gun **316** which may be serially connected with a booster pump **326** and a solenoid valve **328** or the like to control water flow to the end gun **316**. According to a preferred embodiment, the end gun **316** may preferably be mechanically connected to an accelerometer **318** and/or a gyroscopic sensor **324**. The accelerometer **318** may preferably be attached to the end gun **316** to detect vibrations experienced by the end gun **316** during its operations. The gyroscopic sensor **324** may preferably be attached to and oriented with the end gun **316** to detect and transmit the angular velocity and orientation of the end gun **316** as discussed further below.

(22) With reference to FIG. **4**, an exemplary end gun system **400** in accordance with a preferred embodiment of the present invention shall now be discussed. As shown in FIG. **4**, the end gun system **400** may include an end gun main body **402**, a drive arm **404**, a drive spoon **406**, a trip lever **408** and a bearing **410** which may allow the end gun main body **402** to swivel. The end gun system **400** may preferably further include accelerometer **412** and/or gyroscopic sensor **414** as discussed above.

(23) With reference now to FIG. **5**, an exemplary method **500** shall now be discussed. As shown in FIG. **5**, at a preferred first step **502**, the system is preferably initiated and/or powered up. At a preferred second step **504**, the system preferably receives a status update from any linked sensors. At a third step **505**, the system preferably loads, calculates and/or sets initial end gun parameters. These may include ranges of acceleration/vibration values (i.e., acceleration profile data **214**) for given ranges/levels of detected water pressures, locations and the like. These may further include ranges of acceptable orientations/angular velocities for the end gun for given segments of time within an irrigation program or over given ranges of locations (i.e., gyroscopic data ranges).

(24) At a next step **508**, the system may preferably execute a given stored irrigation plan. At a next step **510**, the system may receive accelerometer, gyroscopic, water pressure and/or time data. At a next step **512**, the system preferably compares the received accelerometer data with a stored

acceleration/vibrational event profile for the detected water pressure and/or other irrigation plan parameter(s). If the received accelerometer data is outside of accepted thresholds for the given water pressure or irrigation plan parameter, the system may preferably transmit a notice to the operator (step **518**).

(25) According to a preferred embodiment, the system may compare received accelerometer data with acceleration/vibrational event profile data stored in one or more look-up tables. Preferably, an exemplary look-up table may link acceleration/vibrational event range values with stored water pressure range values and/or time segment values. In this way, the system of the present invention may determine whether the magnitude of a detected acceleration event falls outside of a given, stored acceleration/vibrational range linked to a detected water pressure value (or range of values), or a given time segment of a given irrigation plan.

(26) At a next step **514**, the system preferably receives time and gyroscopic data. At a next step **516**, the system preferably compares the received gyroscopic data with acceptable gyro ranges/thresholds/settings for the detected time segment. As above, if the received gyroscopic sensor data is outside of accepted thresholds for the gyro ranges/thresholds/settings for the detected time segment, the system preferably transmits a notice to the operator (step **518**). Thereafter, the system preferably returns to step **508** and continues executing the irrigation plan.

(27) As discussed above, the system may compare received gyroscopic data with gyroscopic data stored as gyroscopic profile data stored in one or more look-up tables. Preferably, an exemplary look-up table may link gyroscopic event range values (i.e., a discrete value or range of values) with stored end gun orientation/angular velocity range values for a determined time segment and/or water pressure range values. In this way, the system of the present invention may determine whether the magnitude of a gyroscopic event (i.e., a detected orientation, change in orientation, an angular velocity or a change in angular velocity) falls outside of a given, stored gyroscopic range linked to a given detected water pressure value, acceleration value, and/or time segment of a given irrigation plan.

(28) While the above descriptions regarding the present invention contain much specificity, these should not be construed as limitations on the scope, but rather as examples. Many other variations are possible. For example, the processing elements of the present invention by the present invention may operate on a number of different frequencies, voltages, amps and BUS configurations. Further, the communications provided with the present invention may be designed to be duplex or simplex in nature. Further, the systems of the present invention may be used with any arrangement of drive towers including both linear and center pivot systems. Further, as needs require, the processes for transmitting data to and from the present invention may be designed to be push or pull in nature. Still, further, each feature of the present invention may be made to be remotely activated and accessed from distant monitoring stations. Accordingly, data may preferably be uploaded to and downloaded from the present invention as needed.

(29) Accordingly, the scope of the present invention should be determined not by the embodiments illustrated, but by the appended claims and their legal equivalents.

Claims

1. A method for monitoring an end gun within an irrigation system, wherein the method comprises: receiving a status confirmation from a plurality of linked sensors; wherein the plurality of linked sensors comprise a gyroscopic sensor; wherein the gyroscopic sensor is configured to detect at least one of an angular velocity and orientation of the end gun; storing a first set of acceleration profile data; wherein the first set of acceleration profile data comprises a first look-up table linking a first set of vibrational range values with a first set of water pressure range values; storing gyroscopic profile data; wherein the gyroscopic profile data comprises a gyroscopic look-up table linking a first set of end gun orientation range values to a first set of time segment range values; executing a

stored irrigation plan; receiving accelerometer sensor data, water pressure sensor data, gyroscopic sensor data and time segment data; comparing the received accelerometer sensor data to an acceleration range value linked to the water pressure sensor data; comparing the received gyroscopic sensor data to an end gun orientation range value linked to the time segment data; transmitting a first notice if the received accelerometer sensor data is outside of the acceleration range value linked to the water pressure sensor data; transmitting a second notice if the received gyroscopic sensor data is outside of the end gun orientation value for the time segment data; determining a functional status of the end gun based on received accelerometer sensor data; and determining the functional status of the end gun based on received gyroscopic sensor data.
2. The method of claim 1, wherein the method further comprises the step of: calculating oscillations within a span based at least in part on the received accelerometer sensor data and at least in part on the gyroscopic sensor data.
3. The method of claim 1, wherein the method further comprises the step of: calculating oscillations within a span which are parallel to a direction of travel of the span.
4. The method of claim 1, wherein the method further comprises the step of: calculating oscillations within a span which are orthogonal to a direction of travel of the span.
5. The method of claim 1, wherein the method further comprises the step of; determining that a component of the end gun is operating outside of a first set of parameters.
6. The method of claim 1, wherein the method further comprises the step of: determining that a detected water pressure level is below a predetermined level based at least in part on detected levels of vibrations within the end gun.
7. The method of claim 5, wherein the method further comprises the step of: determining whether an end gun is functional based on a detected rate of angular travel over a determined time period.
8. The method of claim 5, wherein the step of determining whether an end gun is functional is a based at least in part on a detected water pressure level.
9. The method of claim 8, wherein the method further comprises a step of: determining a water pressure level based at least in part on a detected rate of angular travel.
10. A method for monitoring an end gun within an irrigation system, wherein the method comprises: receiving a status confirmation from a plurality of linked sensors; wherein the plurality of linked sensors comprise a gyroscopic sensor; wherein the gyroscopic sensor is configured to detect an angular velocity of the end gun; storing a first set of acceleration profile data; wherein the first set of acceleration profile data comprises a first look-up table linking a first set of acceleration event range values with a first set of water pressure range values; storing gyroscopic profile data; wherein the gyroscopic profile data comprises a gyroscopic look-up table linking a first set of end gun angular velocity range values to a first set of time segment range values; executing a stored irrigation plan; receiving accelerometer sensor data, water pressure sensor data, gyroscopic sensor data and time segment data; comparing the received accelerometer sensor data to an acceleration range value linked to the water pressure sensor data; comparing the received gyroscopic sensor data to an end gun angular velocity range value linked to the time segment data; transmitting a first notice if the received accelerometer sensor data is outside of the acceleration range value linked to the water pressure sensor data; transmitting a second notice if the received gyroscopic sensor data is outside of the end gun angular velocity range value for the time segment data; determining a functional status of the end gun based on received accelerometer sensor data; and determining the functional status of the end gun based on received gyroscopic sensor data.
11. The method of claim 10, wherein the method further comprises the step of: calculating oscillations within a span based at least in part on the received accelerometer sensor data and at least in part on the gyroscopic sensor data.
12. The method of claim 10, wherein the method further comprises the step of: calculating oscillations within a span which are parallel to a direction of travel of the span.
13. The method of claim 10, wherein the method further comprises the step of: calculating

oscillations within a span which are orthogonal to a direction of travel of the span.
14. The method of claim 10, wherein the method further comprises the step of: determining that a component of the end gun is operating outside of a first set of parameters.
15. The method of claim 10, wherein the method further comprises the step of: determining that the detected water pressure level is below a predetermined level based at least in part on detected levels of vibrations within the end gun.
16. The method of claim 14, wherein the method further comprises the step of: determining whether an end gun is functional based on a detected rate of angular travel over a determined time period.
17. The method of claim 14, wherein the step of determining whether an end gun is functional is a based at least in part on a detected water pressure level.
18. The method of claim 14, wherein the method further comprises a step of: determining a water pressure level based at least in part on a detected rate of angular travel.