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PLANTER FLEXION IDENTIFICATION

Abstract

An agricultural system including a work implement for fertilizing or planting seed in a field. The work implement includes a toolbar having a first terminating end and a second terminating end, wherein the toolbar includes a plurality of row units. A first sensor is operatively connected to the first end and a second sensor is operatively connected to the second end. The toolbar defines a longitudinal axis, wherein the first sensor identifies a first deflection of the first end with respect to the longitudinal axis and the second sensor identifies a second deflection of the second end with respect to the longitudinal axis. A user interface is operatively connected to the first sensor and to the second sensor, wherein the user interface identifies one or both of the first deflection and the second deflection.

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Background/Summary

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to an agricultural implement, and in particular, to an agricultural implement having a planter or seeder.

BACKGROUND

[0002] An agricultural fertilizer spreader implement or agricultural seed planter implement deposits fertilizer in rows or seed in rows as the implement is pulled by a work vehicle, such as a tractor, through an agricultural field for planting. Combination fertilizer spreaders/planter deposit fertilizer in rows followed by planting seeds along the same row that have received the fertilizer. In these types of agricultural implements, the fertilizer spreader precedes a row crop planter such that the ground is fertilized prior to the seeds being deposited.

[0003] These agricultural implements typically each include a plurality of row units coupled one or more bars supported by tires. A combination of one bar and its row units is also known as a rank. Some agricultural implements include a single bar and other agricultural implements include two or more bars. The bar or bars are inclined with and extend substantially perpendicular to the direction of travel of the work vehicle when pulled through the agricultural field. In the case where fertilizing and/or seeding occurs, a plurality of row units are aligned side by side along one of the bars. In other implementations, multiple bars are located in parallel with one bar following the other to form a multi-rank implement.

[0004] In one implementation, a single bar agricultural implement includes eleven row units on either side of a central location of the implement. The row units are spaced equally apart along the bar. In an agricultural implement configured to either only fertilize or to both fertilize and deposit seeds, the fertilizer row units and seeding row units of the apparatus are aligned and deposit product substantially parallel to the travel direction of the tractor when being pulled through a field.

[0005] Each of the row units include soil engaging components that can include components that open a furrow, place a fertilizer or seed in the furrow, and cover the furrow. Since each of the row units includes components that contact the soil, each row unit as it moves through the soil generates a drag force on the row unit. This drag force, in turn, is transferred to the bar that is coupled to the row unit. The transferred drag force can, under some conditions, generate undesirable forces that flex the bar from its generally perpendicular location with respect to the work machine travel direction. This misalignment may affect the placement of seeds or fertilizer from their intended location.

SUMMARY

[0006] In one implementation there is provided a work implement for fertilizing or planting seed in a field. The work implement includes a toolbar having a first end and a second end, wherein the toolbar includes a plurality of row units. A first sensor is operatively connected to the first end and a second sensor is operatively connected to the second end. The toolbar defines a longitudinal axis, wherein the first sensor identifies a first deflection of the first end with respect to the longitudinal axis and the second sensor identifies a second deflection of the second end with respect to the longitudinal axis. A user interface is operatively connected to the first sensor and the second sensor, wherein the user interface identifies one or both of the first deflection and the second deflection.

[0007] In some implementations there is provided a work implement wherein the toolbar includes a first toolbar having the first end and a first plurality of row units and a second toolbar having the second end and a second plurality of row units, wherein the second toolbar is operatively connected to the first toolbar. The user interface identifies a first location of the first sensor and a second location of the second sensor.

[0008] In some implementations there is provided a work implement further including a first movable joint located at a first jointed end of the first toolbar and a second movable joint located at a second jointed end of the second toolbar, wherein the first location is at the first end of the first toolbar and the second location is at the second end of the second toolbar.

[0009] In some implementations there is provided a work implement wherein the first sensor or the second sensor includes one of an inertial measurement unit (IMU) sensor, a strain gauge, or a pin rotation sensor.
[0010] In some implementations there is provided a work implement wherein at least one of the first sensor, the second sensor, or the third sensor include a GNSS sensor.
[0011] In some implementations there is provided a work implement further including a center frame section including a center toolbar having a third plurality of row units, wherein the center toolbar is operatively connected to the first movable joint and to the second movable joint, wherein the first sensor is located at the first toolbar, the second sensor is located at the second toolbar, and the third sensor is located at a fixed position with respect to the center toolbar.
[0012] In some implementations there is are provided a work implement further including a center frame section having a center toolbar with a third plurality of row units, wherein the center toolbar is operatively connected to the first movable joint and to the second movable joint and the third sensor is located at the center toolbar.
[0013] In some implementations there is provided a work implement wherein the third sensor is fixed with respect to the center frame section and with respect to the longitudinal axis and the first sensor moves from the longitudinal axis with the first deflection of the first toolbar and the second sensor moves from the longitudinal axis with the second deflection of the second toolbar.
[0014] In some implementations there is provided a work implement of including a controller operatively connected to the first sensor, the second sensor, and the third sensor, wherein the controller compares a first location signal provided by the first sensor with a third location signal provided by the third sensor to identify the first deflection and compares a second location signal provided by the second sensor with the third location signal to identify the second deflection of the second toolbar.
[0015] In some implementations there is provided a work implement wherein each of the first GNSS sensor, the second GNSS sensor, and the third GNSS sensor respectively transmit the first location signal, the second location signal, and the third location signal to a cloud system operatively connected to the controller.
[0016] In another implementation there is provided an agricultural system for fertilizing or planting seed in a field. The agricultural system includes a power mover including a propulsion system and a work implement operatively connected to the power mover. The propulsion system moves the work implement through the field in a forward direction to fertilize or plant the seed in the field. The work implement includes a toolbar defining a longitudinal axis and having a plurality of row units, wherein the toolbar includes a first sensor operatively connected to a first end of the toolbar and a second sensor operatively connected to a second end of the toolbar. The first sensor identifies a first deflection of the first end with respect to the longitudinal axis and the second sensor identifies a second deflection of the second end with respect to the longitudinal axis. A user interface is operatively connected to the first sensor and the second sensor, wherein the user interface identifies one or both of the first deflection and the second deflection.
[0017] In some implementations there is provided an agricultural system wherein the toolbar includes a first toolbar and a second toolbar. The first toolbar includes the first end and the first toolbar includes a first rotatable coupling configured to enable the first toolbar to fold with respect to the power mover. A second toolbar includes the second end, wherein the second toolbar includes a second rotatable coupling configured to enable the second toolbar to fold with respect to the power mover. The interface identifies a first location of the first sensor and a second location of the second sensor.
[0018] In some implementations there is provided an agricultural system wherein the first sensor or the second sensor includes one of an inertial measurement unit (IMU) sensor, a strain gauge, or a pin rotation sensor.
[0019] In some implementations there is provided an agricultural system wherein the first sensor

and the second sensor includes a GNSS sensor.
[0020] In some implementations there is provided an agricultural system wherein the work implement includes a center frame section including a center toolbar having a third plurality of row units. The center toolbar is operatively connected to the first rotatable coupling and to the second rotatable coupling and a third sensor is located at a fixed position with respect to the center toolbar.
[0021] In some implementations there is provided an agricultural system wherein the third sensor is located at a fixed position with respect to the longitudinal axis and the first sensor moves from the longitudinal axis with deflection of the first toolbar and the second sensor moves from the longitudinal axis with deflection of the second toolbar.
[0022] In some implementations there is provided an agricultural system further comprising a controller operatively connected to the first sensor, the second sensor, and the third sensor. The controller compares a first location signal provided by the first sensor with a third location signal provided by the third sensor to identify the first deflection and compares a second location signal provided by the second sensor with the third location signal to identify the second deflection of the second toolbar.
[0023] In some implementations there is provided an agricultural system wherein each of the first GNSS sensor, the second GNSS sensor, and the third GNSS sensor respectively transmit the first location signal, the second location signal, and the third location signal to a cloud system operatively connected to the controller.
[0024] In a further implementation there is provided a method of identifying a deflection of a toolbar of a work implement having a plurality of row units. The method includes: identifying a first location of a first end of the toolbar when deflected from a longitudinal axis of the toolbar; identifying a second location of a second end of the toolbar when deflected from the longitudinal axis of the toolbar; comparing the identified first location with respect to a first threshold to identify an amount of a first deflection; comparing the identified second location with respect to a second threshold to identify an amount of a second deflection; and displaying one or both of the amount of the first deflection of the amount of the second deflection on a user interface.
[0025] In some implementations there is provided a method wherein the toolbar includes a first toolbar rotatably coupled to a center toolbar with a first rotatable coupler and includes a second toolbar rotatably coupled to the second toolbar with a second rotatable coupler, wherein the first deflection identifies wear at the first rotatable coupler and the second deflection identifies wear at the second rotatable coupler.
[0026] In some implementations there is provided a method further including moving the work vehicle along a straight line path when comparing the first location of the first end of the toolbar and when comparing the second location of the second end of the toolbar.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0027] The above-mentioned aspects of the present disclosure and the manner of obtaining them will become more apparent and the disclosure itself will be better understood by reference to the following description of the implementations of the disclosure, taken in conjunction with the accompanying drawings.
[0028] FIG. **1** is a top view of an agricultural system including a farm implement pulled by a work vehicle.
[0029] FIG. **2** is a schematic top view of an agricultural system including a single row farm implement pulled by a work vehicle illustrating forces applied to the farm implement when being pulled through a field.
[0030] FIG. **3** is a perspective view of a movable joint for coupling a movable bar to a fixed bar of

a farm implement.
[0031] FIG. **4** is a perspective view of a movable bar aligned with a fixed bar of a farm implement.
[0032] FIG. **5** is a monitoring system for identifying flex in one or more bars of a farm implement.
[0033] FIG. **6** is a monitoring system for identifying flex in one or more bars of a farm implement using one or more global navigation satellite system (GNSS) sensors.
[0034] Corresponding reference numerals are used to indicate corresponding parts throughout the several views.
DETAILED DESCRIPTION
[0035] The implementations of the present disclosure described below are not intended to be exhaustive or to limit the disclosure to the precise forms in the following detailed description. Rather, the implementations are chosen and described so that others skilled in the art may appreciate and understand the principles and practices of the present disclosure.
[0036] Referring to the drawings, and more particularly to FIG. **1**, there is shown an implementation of an agricultural system **10** including an agricultural tool or implement **12**. In the implementation shown, the agricultural tool **12** is a planter, but in other implementations, the agricultural tool **12** is a fertilizer spreader or a seeder. The tool **12** includes a toolbar **14** supported by wheels **15**. A work vehicle **16**, in the form of a tractor, includes a hitch **18** that may be coupled to and move the implement **12** with a suitable coupling arrangement, i.e. towing assembly **20**. The towing assembly **20** includes drawbars **22** coupled to the hitch **18** and coupled to the toolbar **14**. implementations are contemplated including an autonomous machine including a propulsion system having a power mover, such as an engine, pulling the implement **12**, as well as an entirely self-contained autonomous fertilizer/seeder implement, including the row units and a propulsion system, are a complete and unitary seeding system. The implement **12** includes a liquid fertilizer tank **24** and seed hoppers **26**.
[0037] In the case of a seeder, the frame/toolbar on a seeder can have up to five (5) sections and may use a separate commodity cart. If a commodity cart is used, the commodity cart may be used as mounting location for the GNSS sensor, in addition to mounting the GNSS sensor on the tractor, on the center toolbar, or on a separate connected implement.
[0038] The toolbar **14** includes a number of row units **28**. In some implementation, each of the row units **28** include a seed hopper **29**. In other implementations, the row units **28** do not include a seed hopper, but receive seed from a centrally located and larger seed hopper or tank, such as seed hopper **26**. A center toolbar **30**, which is fixedly coupled to a center frame section **32**, supports the row units **28**. A first toolbar **34** extends from the center toolbar **30** in a first direction and a second toolbar **36** extends from the center toolbar **32** in a second direction. During a planting operation, the center toolbar **30**, the first toolbar **34**, and the second toolbar **36** are aligned along the same longitudinally extending axis extending from one end of the toolbar **14** to another end of the toolbar **14**.
[0039] The first toolbar **34** is rotatably coupled to the center toolbar **30** at a first rotatable coupler **38** and the second toolbar **36** is rotatably coupled to center toolbar **30** by a second rotatable coupler **40**. Each of the first toolbar **34** and the second toolbar **36** rotate about respective first rotatable coupler **38** and second rotatable coupler **40** for folding toward the work vehicle **16**. Once folded, the implement **12** may be transported along a road due to the collapsed nature of the implement **12**, as would be understood by one skilled in the art. In other implementations, each of the first toolbar **34** and the second toolbar **36** includes an inner wing and an outer wing, which are also foldable with respect to one another for transportation.
[0040] FIG. **2** is a schematic top view of the agricultural system **10** including the farm implement **12** pulled by the tractor **16** illustrating forces applied to the farm implement **12** when being pulled through a field. As the farm implement **12** is pulled through the field in a forward direction **42**, each of the row units **28**, represented schematically, applies a drag force to the center frame section **32**, the first toolbar **34**, and the second toolbar **36**. While the drag forces applied by each of the row

units **28** may be substantially equal, depending on soil conditions, the drag forces applied towards an end **46** of first toolbar **34** and an end **48** of second toolbar **36** tend to move end **46** and end **48** in respective directions **50** and **52**. The movement in directions **50** and **52** may result from accumulated forces applied to each of the first and second toolbars **34** and **36** from drag forces applied to the soil during implement **12** movement along the field. These drag forces result from the soil engaging component of the row units **28** that engage the soil to open or close furrows. In addition, the movement in directions **50** and **52** also results from the length of each of the first toolbar **34** and the second toolbar **36**.

[0041] As seen by arrows **54** and **56**, the toolbars **34** and **36** tend to bend in the direction of arrows **54** and **56** resulting in a curved or bent condition as shown by the curvature of arrows **54** and **56**. Arrows **54** and **56** generally show a condition of bending or curvature, but are not intended to illustrate an amount of curvature or bending experienced by each of the first toolbar **34** and the second toolbar **36**.

[0042] Since each of the first and second toolbars **34** and **36** may experience bending, the row units **28** located towards the ends **46** and **48** of the toolbars **34** and **36** may no longer be aligned with a central longitudinal axis **58** defined by the toolbars when manufactured to a nominal design. One or both of the toolbars due to the bending or flexion are deflected from the longitudinal axis. Consequently, one or both of the toolbars experiences a deflection, and one or more of the row units **28** may no longer track an intended furrow, with the result being an improper placement of seeds or fertilizer. In addition, use of the implement **12** over time may result in mechanical wear to the toolbars **34** and **36** as well mechanical wear to mechanical joints, such as first rotatable coupler **38** and second rotatable coupler **40**. Extended use of the implement **12** increases mechanical wear leading to misalignment of row units. The mechanical wear damages the implement **12** that requires repair or replacement.

[0043] In one implementation as illustrated, the toolbar **34** includes fourteen (14) row units **28**, the toolbar **36** includes 14 row units **28**, and the center frame section **32** includes eight (8) row units **28**. Other implementations are also contemplated and include other numbers of row units. In some implementation, the number of row units is not the same from side toolbar to another side toolbar. In still other implementations, the number of row units is not the same for one side toolbar to another side toolbar. In some situations, the operator may remove one or more row units from one side only such that the number of row units is not the same for one toolbar to another toolbar.

[0044] FIG. **3** is a perspective view of a movable joint **60** for coupling a movable bar **62** to a fixed bar **64** of a farm implement **12**. In one implementation, the movable joint **60** corresponds to movable joint **38** of FIG. **2**. Other configurations of movable joints are contemplated. The fixed bar **64** is located at the center frame section **32** which supports row units **28**. The movable bar **62** corresponds to the first toolbar **34**. As described above, the movable joint **60** enables folding of the first toolbar **34** in a forward position for moving the implement **12** along a road, for instance. Since this movable joint **60** experiences both rotational forces when being folded and unfolded, additional undesirable forces may be experienced when the implement is being transported along a road or field in the folded condition. Undesirable wear may therefore occur at movable joint **60**. In one implementation, the movable joint includes a pin **61** about which the first toolbar **34** rotates. Toolbar **36** includes a similar configuration including a movable joint at rotatable coupler **40** and experiences undesirable wear.

[0045] To use the implement for planting, the first toolbar **34** is moved to an aligned condition with the center frame section **32** as illustrated in FIG. **4**. In this condition, the first toolbar **34** is aligned with the center frame section **32** along the axis **58** of FIG. **2**. The second toolbar **36** is aligned with the center frame section **32**. The movable joint **60** and the movable joint at location **40** of toolbar **36** experiences less damage from rotational movement of the joint **60** in this position, but other forces experienced at the joint(s) may occur. For instance, the first tool bar **34** and second toolbar **36** may experience forces in a vertical direction **66** or torsional forces as the implement **12** is pulled over the field, for instance in response to undulating ground.

[0046] Forces experienced by the first tool bar **34** during planting may occur in other directions as well, since the ground does not rise and fall in a predictable pattern. Not only do these forces affect the joint **60**, but such forces may affect a beam strength of materials used to make the tool bar **34**. For instance, in one implementation, the tool bar **34** includes square beams that may experience torsional forces as well as other straight line direction forces. Consequently, the forces experienced by the first toolbar **34** and the second toolbar **36** may result from a multitude of different directions, each of which may affect the position and alignment of the row units **28** during use.

[0047] As seed is planted, flexion or flexing of the bars causes seeds, or fertilizer, to be placed in different positions than what is determined by an original condition of the implement. Thus the tracking placement of the seed, or fertilizer, is incorrect. This flexion can be caused by slopes, varying ground compaction, levels of ground moisture, and impediments to correct placement of seed. As used herein flexion means a bending or flexing experienced by a mechanical system, apparatus, tool, implement, or device.

[0048] Some customers may adjust the spacing of the row units, and some customers may remove row units. When removing units, this could create an odd number of units side to side. The flexion measurement could be used to measure the ‘balance’ of the planter bar. When the balance is off, an alert is transmitted to a user interface such as user interface **80** of FIG. **5** or **6**. The alert notifies the operator to make an adjustment to the tool bars so that the row units travel along a straight line within the field.

[0049] Flexion of the tool bars may also result from mechanical wear or ‘looseness’ of the mechanical joints on the overall frame. Flexion may continue to increase over time, and wear may be indicated. When the joints are tight (or within spec), the flexion may return to a static value most of the time during operation since the forces causing flexing change and return to a more normal state. When the joints are worn, however, the flexion remains during most operations. In this case, the wear may results from flexion at the movable joints, also known as folding joint(s), at locations **38**, **40**, and elsewhere.

[0050] To identify flexion, one or more sensors **70** are coupled to the implement **12** as seen in FIG. **2**. In FIG. **2**, a sensor **70**A is coupled to an end **72** of first toolbar **34** and a sensor **70**B is coupled to an end **74** of second toolbar **36**. In some implementations, and as illustrated in FIG. **2**, the sensors **70**A and **70**B are located at terminating ends of the first toolbar **34** and second toolbar **36**. In other implementations, the sensors **70**A and **70**B are not located at terminating ends of the toolbar and other locations are contemplated. For instance, sensors may be located towards ends of the toolbar so that deflection may be measured. Sensors may also be located toward a middle of that toolbar as long as deflection can be measured. In one or more implementations, different types of sensing devices or sensor may be employed. For instance, sensing devices include, but are not limited to, global navigation satellite system (GNSS) sensors, inertial measurement unit (IMU) sensors, strain gauges, and pin rotation sensors where pins are used at rotatable joints such as joint **60**. One or more of each of the GNSS sensors, inertial measurement unit (IMU) sensors, strain gauges, and/or pin rotation sensors, in different implementations, may be used as stand-alone measurement sensors that are located at or across a joint. In one implementation, one sensor is located at the rotatable joint **38** between the center frame **32** and the first toolbar **34**, and at the rotatable joint **36** between the center frame **32** and the second toolbar **36**. As described herein, a stand-alone measurement sensor is one which provides an indication of flexion at a particular location, such as at a rotatable joint. While GNSS sensors generally review generically to satellite systems, other specific types of GNSS sensor are contemplated. For instance, Europe has Galileo as a GNSS sensor, Russia has GLONASS as a GNSS sensor, China has BeiDou as a GNSS sensor, and the US has GPS as a GNSS sensor.

[0051] In one implementation illustrated in FIG. **5**, the work vehicle **16** includes a user interface **80** including an alert indicator **82** and a sensor location display **84** to identify a sensor location at which flexion is identified. In one implementation, a controller **86** is operatively connected to the user interface **80** as well as to sensors **70**A, **70**B, and a sensor **70**C coupled to the center toolbar **32**. In another implementation, the senor **70**C is not included. See FIG. **1**, for instance, where the user interface **80** is located in the cab **17** of the tractor **16**.

[0052] Each of the sensors **70**A and **70**B transmits a location signal to the controller **86** indicated respectively the location of ends **72** and **74**. The controller **86** executes or otherwise relies upon computer software applications, components, programs, objects, modules, or data structures, etc. Software routines, i.e. software, resident in the included memory, are executed in response to the signals received from the sensors or through CAN bus. In other implementations, the computer software applications are located in a memory internal to the controller **86** or external to the controller **86**, including the "cloud". The executed software includes one or more specific applications, components, programs, objects, modules or sequences of program instructions typically referred to as "program code". The program code includes one or more program instructions located in memory and other storage devices that execute the instructions that are resident in memory, which are responsive to other program instructions or machine settings generated by the system.

[0053] Upon receipt of the location signals, the controller **86** compares the received location signals to a predetermined location value, wherein the predetermined location value identifies an original design value indicative of the original position of each of the ends **72** and **74**. The controller **86** compares the original design value(s) to the received location signals to determine whether flexion is occurring. In one implementation, the controller **86** compares threshold values that are used in the comparison to determine whether an identified flexion has exceeded the threshold values. If the identified flexion, also known as an amount of deflection, has exceeded the threshold values, the alert **82** is activated to indicate to an operator that flexion has occurred. In one implementation, the threshold values are determined based on original design constraints.

[0054] In another implementation, a sensor **70**C is located at the center toolbar **32**. This sensor transmits a location signal of the sensor **70**C to the controller **86**. The value of this sensor **70**C is compared to either one or both of sensor location signals **70**A and **70**B.

[0055] FIG. **6** illustrates another implementation of a control system to identify flexion in the implement **12**. In this implementation, the user interface **80**, which includes the alert **82** and sensor location **84**, is operatively connected to a controller **90**. The controller **90** is configured to transmit and receive signals from a vehicle antenna **92**. The vehicle antenna **92** is operatively connected to a cloud system **94** that utilizes the internet. In this implementation, a first GNSS sensor **96** is coupled to the end **72** of the first toolbar **34** and a second GNSS sensor **98** is coupled to the end **74** of the second toolbar **36**. Each of the first and second GNSS sensors **96** and **98** include transmitters configured to transmit location information of the ends **72** and **74** to the cloud system **94**. A third GNSS sensor **100** is coupled to the center toolbar **32** and remains at a fixed position with respect to either of the first GNSS sensor **96** and the second GNSS sensor **98**.

[0056] Each of the first, second, and third GNSS sensor are aligned along the longitudinal axis **58**. As long as the implement **12** is stationary and the implement **112** has not experienced wear that causes flexion, location information from each of the GNSS sensors transmits the same or similar location information for being located substantially along the axis **58**. Once the implement **12** is in motion while planting or fertilizing, the GNSS sensor **96** and/or the GNSS sensor **98** may transmit signals that indicate an amount of flexion. Since the central toolbar **32** does not flex, the signal transmitted by the GNSS sensor **100** indicates the location of the longitudinal axis **58**. In one implementation, each of the location signals transmitted by each of the GNSS sensor **96**, **98**, and **100** to the cloud system **94**. The location signals received at the cloud system **94** are transmitted to the vehicle antenna **92** from the cloud system **94** to the controller **90**. The controller **90** compares the sensor location signal of GNSS sensor **100** to one or both of the sensor location signals of GNSS sensor **96** and GNSS sensor **98**. A deviation of either sensor location signals of GNSS sensor

96 or GNSS sensor **98** to the location signal of GNSS sensor **98** indicates a flexion of one or both of the first toolbar **34** or the second toolbar **36**.

[0057] In one implementation, the controller **90** compares a flexion threshold value to an identified flexion at GNSS sensor **96** and/or GNSS sensor **98** to determine if the identified flexion has exceeded the flexion threshold value. If the identified flexion has exceeded the threshold value, the alert **82** is activated to indicate to an operator that flexion has occurred.

[0058] In another implementation, the third GNSS sensor **100** may be located at the tractor **16**, for instance at the cab **17**, as opposed to being located at the center section **32**. See FIG. **1**, for instance. The location of the third GNSS sensor **100** at the tractor, or at the center toolbar **32**, is identified with respect to each of the GNSS sensors, sensor **96** and the sensor **98**. By knowing the location of each of the GNSS sensors **96**, **98**, with respect to GNSS sensor **100**, the amount of flexion with respect to the fixed GNSS sensor **100** is identifiable. The identification may be used to determine deflection of ends **72** and **74** with respect to the cab location of GNSS sensor **100**, by using triangulation for instance. When the GNSS sensor **100** is located at either the center toolbar **32** or at the tractor **16**, the GNSS sensor **100** operates as a “home” sensor whose location remains fixed with respect to the remaining sensors **96** and **98**. Deflection for the ends of the toolbar where GNSS sensors **96** and **98** with respect to “home” sensor may then be determined.

[0059] In other implementations, deflection of the toolbar **14** may be determined at each of the joints **48** and **40** using one or more of the global positioning system (GNSS) sensors, inertial measurement unit (IMU) sensors, strain gauge sensors, and pin rotation sensors, as stand-alone measurement sensors which are located at or across the joints. In one implementation, one sensor is located at the rotatable joint **38** between the center frame **32** and the first toolbar **34**, and one sensor is located at the rotatable joint **36** between the center frame **32** and the second toolbar **36**. In another implementation, deflection of the toolbar is determined using one sensor as a

[0060] To identify deflection of the toolbar, the tractor **16** is directed to move in a straight line forward direction. When moving in the straight line forward direction, the drag produced by the row units and other features of the toolbar is considered to be relatively constant, such that any changes in terrain as the tractor **16** moves forward are minimized. The identification of flexion, therefore, is made by reducing undesirable effects that irregular terrain conditions may produce.

[0061] When using GNSS sensors **96**, **98**, **100** and moving in the straight line direction, each sensor provides a GNSS vector signal, i.e. a direction signal, having the same heading or straight line direction. In one example, the straight line direction is maintained using a tractor steering angle of approximately plus or minus 3 degrees about a zero degree straight line. The straight line direction is generally parallel to the forward moving direction of the tractor **16**. The straight line direction is adjusted by a vehicle steering mechanism **102** in response to one of an operator control, such a steering wheel, or autonomous control. When being controlled, the steering mechanism transmits a steering control signal to the controller **90**. In different implementations, the vehicle steering mechanism includes Ackerman steering or articulated steering on the tractor. Other types of steering mechanisms are contemplated.

[0062] In one implementation, the controller **90** compares the steering control signal to a threshold value, such as the plus or minus the 3 degrees value. As the tractor **16** moves forward, the directional vectors each have headings of the same direction, if there is no toolbar deflection. Based on the resulting comparison made to identify steering direction, a value of the comparison is displayed on the user interface **80** to provide a real time comparison to the operator. As the operator views the real time comparison, the operator may adjust the tractor's steering to maintain the straight line direction within the straight line threshold values. As the tractor moves forward along the straight line, the controller **90** generates values of flexion experienced by the first toolbar **34** or the second toolbar **36**. If the values of flexion are greater that the flexion threshold value, the controller **90** may generate an indicator shown on the user interface **80** to indicate the occurrence of excess flexion. Once indicated, the operator may note the excess flexion using a store button located at the user interface **80**. In other implementations, the real time comparison is not shown and the controller **90** only generates a flexion alert at the user interface to indicate that excess flexion has occurred. In some implementations, the flexion alert includes an audible alert. In other implementations, the directional vector signals are transmitted to the cloud system where comparisons to determine flexion are determined.

[0063] In a further implementation, if the toolbar is traveling in an arc, flexion may also be determined. For instance, if the system of FIG. **1** the system is traveling straight, forces acting on toolbars **34** and **36** will be relatively equal (ignoring soil and row unit variation). If the system is turning to the left, however, toolbar **36** starts traveling faster than toolbar **34**, and toolbar **36** may experience more flexion as a result and this flexion may be more identifiable knowing the direction of turning. If the 3rd sensor is on the tractor, the pivot point at the hitch may make this more difficult, but flexion may be able to be determined.

[0064] The identified flexion may be used as a way to understand mechanical wear, “looseness” of the mechanical joints on the overall frame, or wear to the toolbars. As flexion increases over time, the amount of flexion may indicate that wear to the mechanical joints or toolbars is or has occurred. When the mechanical joints are tight or within specifications, such as when new or when replaced, the flexion values will return to a static value most of the time during operation. However, when the joints or other mechanical systems or apparatus are worn, the wear, and therefore the flexion, will remain during most operations. In one or more implementations, the wear would likely be present at the folding joint(s).

[0065] Flexion identification may also be used to identify an issue with a tire/wheel/hub assembly on one of the outside wheels, wheels located towards end **72** and **74**. A wheel not turning properly may produce increased drag on the side of the implement, which could be measured by identifying flexion.

[0066] In one or more implementations, the controller **90** continuously receives signal data from the sensors that identify the amount of flexion. This signal data may be stored in a memory associated with the controller **90**. The stored data is compared with the threshold over a period of time to determine a change in flexion over time. The change in flexion over time h be used to identify trends related to mechanical wear. For instance, if a change in flexion occurs relatively rapidly over time, such a change may represent a breakage, which may require repair or replacement of parts or other components of the mechanical systems. More gradual changes to flexion may indicate wear resulting from use. Changes over time may be displayed at the user interface **80** to alert the user or a break or of wear. A change in the amount of flexion over time may be used as an indicator that the mechanical system needs maintenance.

[0067] In another implementation, the cloud system **94** is configured to compare each of the location signals transmitted by each of the GNSS sensors **96**, **98**, to the location signal of GNSS sensor **100** to identify flexion. If the comparison identifies flexion, this flexion is transmitted to the vehicle antenna **92** that is then received by the controller **90**. Once received, the controller **90** causes the alert **82** to indicate flexion when it occurs.

[0068] In further implementations, the agricultural implement includes a controller located on the implement that identifies the flexion of the implement. In this way, the agricultural implement having this feature may be used with a variety of different work vehicles. In one exemplary implementation, the agricultural implement includes a transmission device to transmit flexion information either to the cloud or to the work vehicle. In another implementation, the sensors transmit flexion information to the cloud and a controller located on the cloud determines flexion. The result of the flexion measurement at the cloud is then transmitted to an operator located at the work vehicle. If the system **10** is an autonomous system, the result of the flexion measurement is transmitted to operators or users not located at the work vehicle **16**.

[0069] While exemplary implementations incorporating the principles of the present disclosure have been described hereinabove, the present disclosure is not limited to the described implementations. Instead, this application is intended to cover any variations, uses, or adaptations of the disclosure using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains and which fall within the limits of the appended claims.

Claims

1. A work implement for fertilizing or planting seed in a field, the work implement comprising: a toolbar including a first end and a second end, the toolbar including a plurality of row units spaced along the toolbar and between the first end and the second end; a first sensor operatively connected to the first end; a second sensor operatively connected to the second end; wherein the toolbar defines a longitudinal axis, and the first sensor identifies a first deflection of the first end with respect to the longitudinal axis and the second sensor identifies a second deflection of the second end with respect to the longitudinal axis; and a user interface operatively connected to the first sensor and the second sensor, wherein the user interface identifies one or both of the first deflection and the second deflection.
2. The work implement of claim 1, further comprising a center toolbar, wherein the toolbar includes a first toolbar coupled to the center toolbar and having the first end and a first plurality of row units, and a second toolbar coupled to the center toolbar and having the second end and a second plurality of row units, the second toolbar operatively connected to the first toolbar through the center toolbar; and wherein the first sensor identifies the first deflection of the first toolbar and the second sensor identifies the second deflection of the second toolbar.
3. The work implement of claim 2 further comprising a first movable joint located at a first jointed end of the first toolbar with the center toolbar and a second movable joint located at a second jointed end of the second toolbar with the center toolbar, wherein the first sensor is located at the first jointed end and the second sensor is located at the second jointed end.
4. The work implement of claim 3 wherein the first sensor is located at the first jointed end and the second sensor is located at the second jointed end, wherein the first sensor and the second sensor includes one of an inertial measurement unit (IMU) sensor, a strain gauge, a pin rotation sensor, or a GNSS sensor.
5. The work implement of claim 3 further comprising a third sensor, wherein the first sensor, the second sensor, and the third sensor includes a GNSS sensor.
6. The work implement of claim 5 further comprising a center frame section including the center toolbar having a third plurality of row units, wherein the center toolbar is operatively connected to the first movable joint and to the second movable joint, wherein the first sensor is located at the first toolbar, the second sensor is located at the second toolbar, and the third sensor is located at a fixed position with respect to the center toolbar.
7. The work implement of claim 6 wherein the third sensor is fixed with respect to the center frame section and with respect to the longitudinal axis and the first sensor moves from the longitudinal axis with the first deflection of the first toolbar and the second sensor moves from the longitudinal axis with the second deflection of the second toolbar.
8. The work implement of claim 7 comprising a controller operatively connected to the first sensor, the second sensor, and the third sensor, wherein the controller compares a first location signal, provided by the first sensor, with a third location signal, provided by the third sensor, to identify the first deflection, and compares a second location signal, provided by the second sensor, with the third location signal to identify the second deflection of the second toolbar.
9. The work implement of claim 8 wherein each of the first GNSS sensor, the second GNSS sensor, and the third GNSS sensor respectively transmit the first location signal, the second location signal, and the third location signal to a cloud system operatively connected to the controller.
10. An agricultural system for fertilizing or planting seed in a field, the agricultural system

comprising: a power mover including a propulsion system; a work implement operatively connected to the power mover, wherein the propulsion system moves the work implement through the field in a forward direction to fertilize or plant the seed in the field, wherein the work implement includes a toolbar defining a longitudinal axis and having a plurality of row units, the toolbar including a first sensor operatively connected to a first end of the toolbar and a second sensor operatively connected to a second end of the toolbar, wherein the first sensor identifies a first deflection of the first terminating end with respect to the longitudinal axis and the second sensor identifies a second deflection of the second terminating end with respect to the longitudinal axis; and a user interface operatively connected to the first sensor and the second sensor, wherein the user interface identifies one or both of the first deflection and the second deflection.
11. The agricultural system of claim 10 wherein the toolbar includes a first toolbar having the first end, first toolbar including a first rotatable coupling configured to enable the first toolbar to fold with respect to the power mover and a second toolbar having the second end, the second toolbar including a second rotatable coupling configured to enable the second toolbar to fold with respect to the power mover, wherein the user interface identifies a first location of the first sensor and a second location of the second sensor.
12. The agricultural system of claim 11 wherein the first sensor or the second sensor includes one of an inertial measurement unit (IMU) sensor, a strain gauge, or a pin rotation sensor.
13. The agricultural system of claim 11 wherein the first sensor and the second sensor includes a GNSS sensor.
14. The agricultural system of claim 11 wherein the work implement includes a center frame section including a center toolbar having a third plurality of row units, wherein the center toolbar is operatively connected to the first rotatable coupling and to the second rotatable coupling and a third sensor is located at a fixed position with respect to the center toolbar.
15. The agricultural system of claim 14 wherein the third sensor is located at a fixed position with respect to the longitudinal axis and the first sensor moves from the longitudinal axis with deflection of the first toolbar and the second sensor moves from the longitudinal axis with deflection of the second toolbar.
16. The agricultural system of claim 15 further comprising a controller operatively connected to the first sensor, the second sensor, and the third sensor, wherein the controller compares a first location signal provided by the first sensor with a third location signal provided by the third sensor to identify the first deflection and compares a second location signal provided by the second sensor with the third location signal to identify the second deflection of the second toolbar.
17. The agricultural system of claim 16 wherein each of the first GNSS sensor, the second GNSS sensor, and the third GNSS sensor respectively transmit the first location signal, the second location signal, and the third location signal to a cloud system operatively connected to the controller.
18. A method of identifying a deflection of a toolbar of a work implement having a plurality of row units, the method comprising: identifying a longitudinal axis of the toolbar; comparing a first location of a first end of the toolbar with respect to the longitudinal axis to identify an amount of a first deflection of the first end; comparing a second location of a second end of the toolbar with respect to the longitudinal axis to identify an amount of a second deflection o the second end; displaying one or both of the amount of the first deflection of the amount of the second deflection on a user interface.
19. The method of claim 18 wherein the toolbar includes a first toolbar rotatably coupled to a center toolbar with a first rotatable coupler and includes a second toolbar rotatably coupled to the center toolbar with a second rotatable coupler, wherein the first deflection identifies wear at the first rotatable coupler and the second deflection identifies wear at the second rotatable coupler.
20. The method of claim 19 further comprising moving the work vehicle along a straight line path

when comparing the first location of the first end of the toolbar and when comparing the second location of the second end of the toolbar.