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(54) **WING FORCE MANAGEMENT SYSTEM FOR AN AGRICULTURAL IMPLEMENT**

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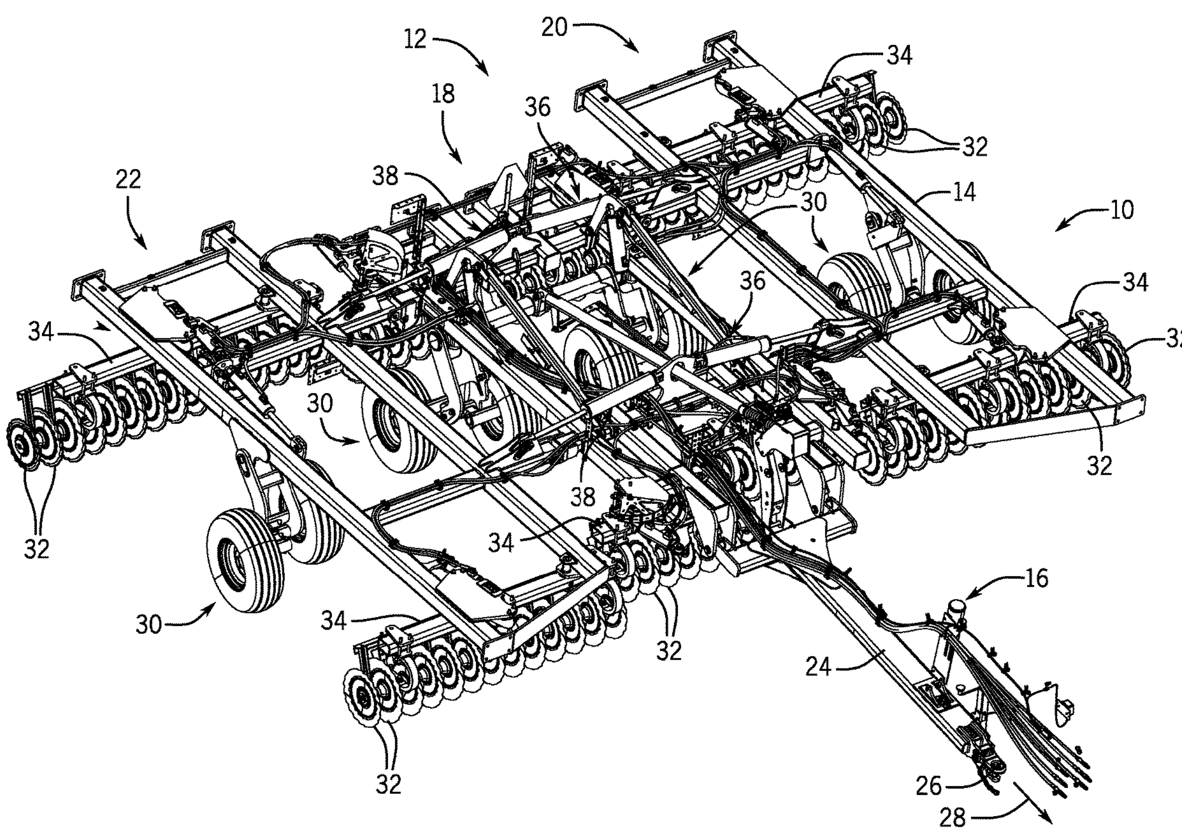
(57) **ABSTRACT**

A wing force management system of an agricultural implement includes a hydromechanical linkage assembly coupled to a frame of the agricultural implement. The hydromechanical linkage assembly includes a blocking valve fluidly coupled to a valve assembly. The valve assembly may control a wing fold cylinder of the agricultural implement, which may drive a wing section of the frame to rotate relative to a center section of the frame. A driver coupled to the frame of the agricultural implement may actuate the blocking valve in response to rotation of the wing section to control the valve assembly to adjust fluid pressure within the wing fold assembly.



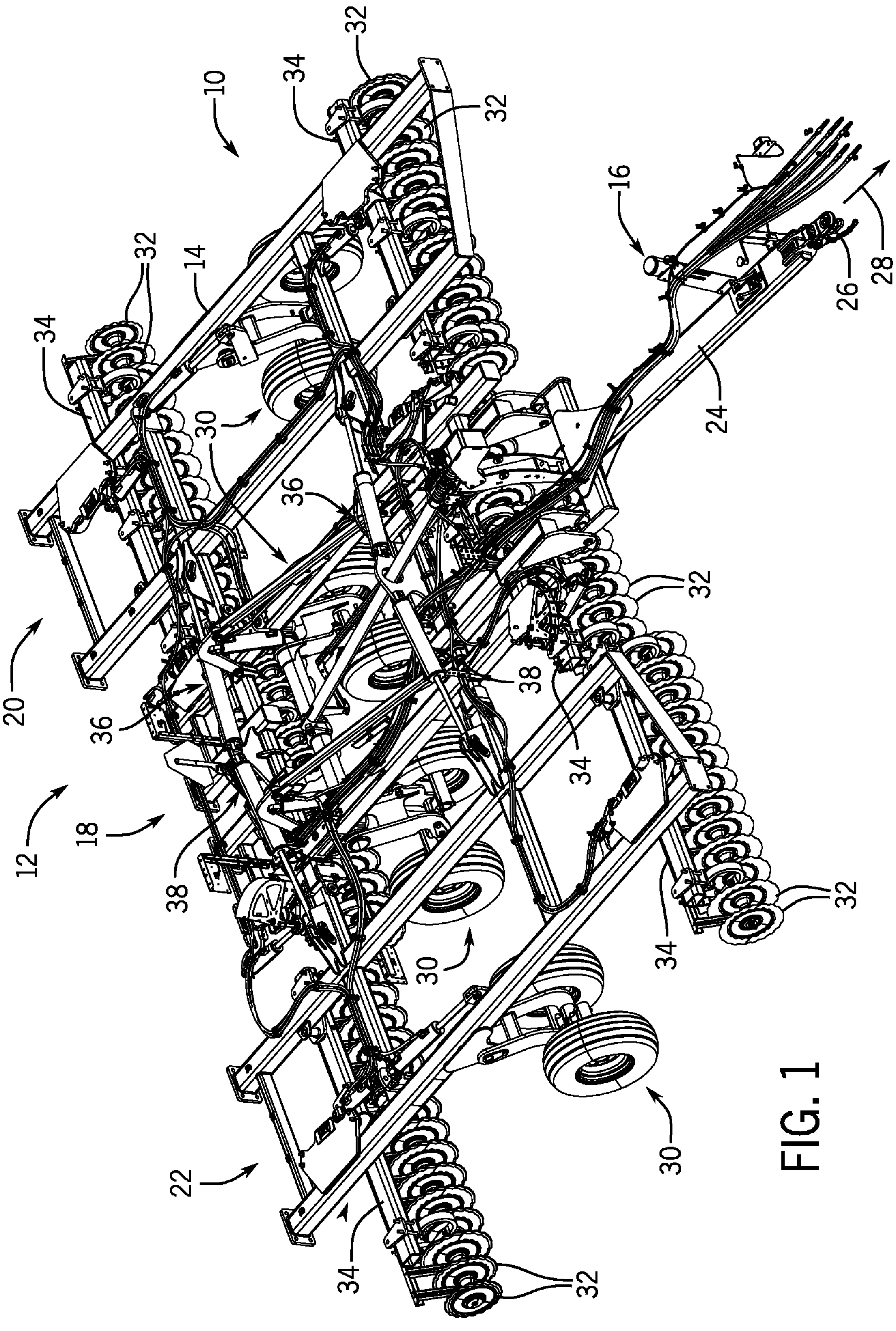


FIG. 1

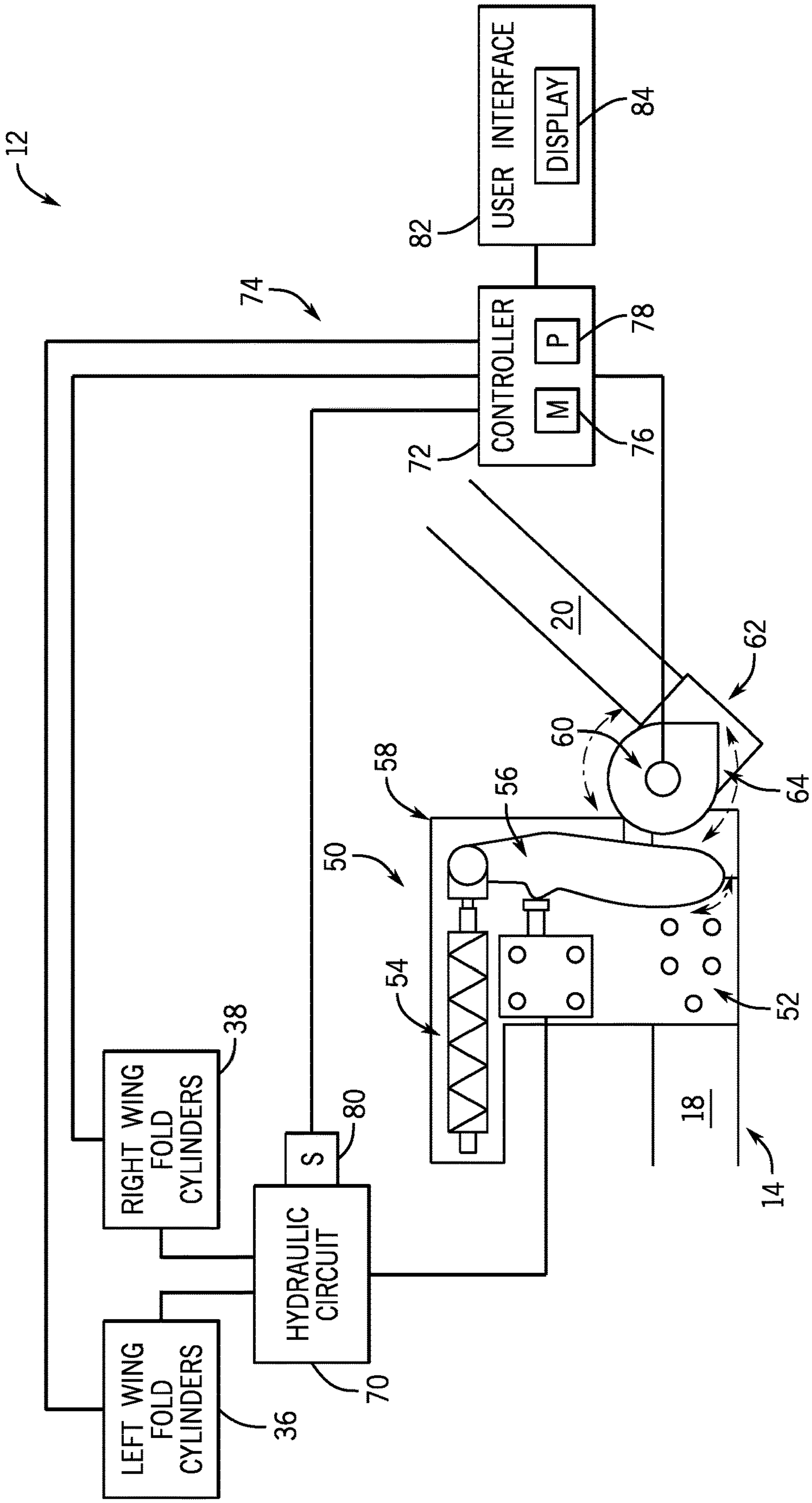

12
USER INTERFACE
DISPLAY
82
84
74
CONTROLLER
M
P
72
76
78
20
62
60
64
58
56
50
54
52
18
14
RIGHT WING FOLD CYLINDERS
38
S
80
HYDRAULIC CIRCUIT
70
LEFT WING FOLD CYLINDERS
36

FIG. 2

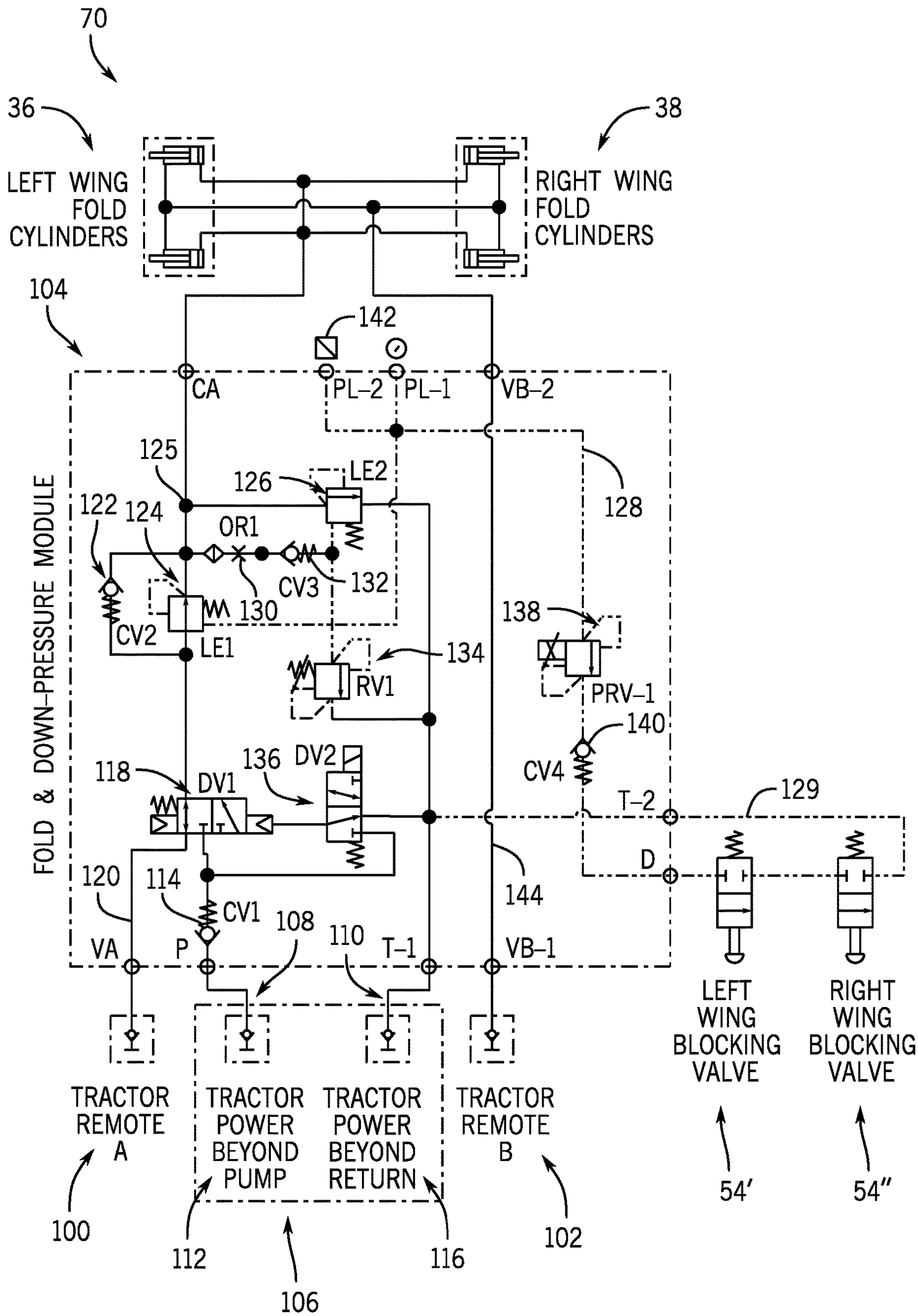

70
36
38
LEFT WING FOLD CYLINDERS
RIGHT WING FOLD CYLINDERS
104
142
CA
PL-2
PL-1
VB-2
FOLD & DOWN-PRESSURE MODULE
125
126
LE2
128
122
124
OR1
130
CV3
132
CV2
LE1
138
134
RV1
PRV-1
140
CV4
118
DV1
136
DV2
T-2
129
D
120
114
CV1
108
110
144
VA
P
T-1
VB-1
TRACTOR REMOTE A
TRACTOR POWER BEYOND PUMP
TRACTOR POWER BEYOND RETURN
TRACTOR REMOTE B
LEFT WING BLOCKING VALVE
RIGHT WING BLOCKING VALVE
100
112
106
116
102
54′
54″

FIG. 3

WING FORCE MANAGEMENT SYSTEM FOR AN AGRICULTURAL IMPLEMENT

BACKGROUND

[0001] The present disclosure relates generally to a wing force management system for an agricultural implement.

[0002] Certain agricultural implements include ground engaging tools configured to interact with soil. For example, a tillage implement may include disc blades configured to break up the soil for subsequent planting or seeding operations. Groups of disc blades may be arranged in gangs, and each gang of disc blades may be rotatably coupled to a frame of the tillage implement. In certain tillage implements, the frame may include wing sections that may rotate between a working position and a transport position. Hydraulic cylinders may drive the wing sections to rotate between the working position (e.g., lowered position) and the transport position (e.g., raised position). Penetration depths of the disc blades on each wing section may be limited by the mass of the wing section.

SUMMARY OF THE INVENTION

[0003] In certain embodiments, a wing force management system of an agricultural implement may include a hydromechanical linkage assembly coupled to a frame of the agricultural implement. The hydromechanical linkage assembly may include a blocking valve fluidly coupled to a valve assembly. The valve assembly may control a wing fold cylinder of the agricultural implement, which may drive a wing section of the frame to rotate relative to a center section of the frame. When the wing section rotates, a driver coupled to the frame of the agricultural implement may actuate the blocking valve to adjust fluid pressure within the wing fold assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0005] FIG. **1** is a perspective view of an embodiment of an agricultural implement having a wing force management system;

[0006] FIG. **2** is a schematic view of an embodiment of a wing force management system that may be employed within the agricultural implement of FIG. **1**; and

[0007] FIG. **3** is a schematic diagram of an embodiment of a hydraulic circuit that may be employed within the wing force management system of FIG. **2**.

DETAILED DESCRIPTION

[0008] One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0009] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Any examples of operating parameters and/or environmental conditions are not exclusive of other parameters/conditions of the disclosed embodiments.

[0010] FIG. **1** is a perspective view of an embodiment of an agricultural implement **10** (e.g., tillage implement) having a wing force management system **12**. In the illustrated embodiment, the tillage implement **10** is a vertical tillage implement having multiple ground engaging tools configured to till soil. As illustrated, the tillage implement **10** includes a frame **14** and a hitch assembly **16** coupled to the frame **14**. The frame **14** may be formed from multiple frame elements (e.g., rails, tubes, braces, etc.) coupled to one another (e.g., via welded connection(s), via fastener(s), etc.). In the illustrated embodiment, the frame **14** includes a center section **18**, a left wing section **20**, and a right wing section **22**. Each wing section is configured to rotate upwardly from the illustrated working position to a transport position to facilitate transport of the tillage implement **10**. As discussed in detail below, actuators (e.g., hydraulic cylinders, etc.) are configured to drive the wing sections to rotate between the illustrated working position and the transport position.

[0011] In the illustrated embodiment, the hitch assembly **16** includes a hitch frame **24** and a hitch **26**. The hitch frame **24** is pivotally coupled to the implement frame **14** via pivot joint(s), and the hitch **26** is configured to couple to a corresponding hitch of a work vehicle (e.g., tractor), which is configured to tow the tillage implement **10** through a field along a direction of travel **28**. While the hitch frame **24** is pivotally coupled to the implement frame **14** in the illustrated embodiment, in other embodiments, the hitch frame may be movably coupled to the implement frame by a linkage assembly (e.g., four bar linkage assembly, etc.) or another suitable assembly/mechanism that enables the hitch to move along a vertical axis relative to the implement frame, or the hitch frame may be rigidly coupled to the implement frame.

[0012] As illustrated, the tillage implement **10** includes wheel assemblies **30** movably coupled to the implement frame **14**. In the illustrated embodiment, each wheel assembly **30** includes a wheel frame and a wheel rotatably coupled to the wheel frame. The wheels of the wheel assemblies **30** are configured to engage the surface of the soil, and the wheel assemblies **30** are configured to support at least a portion of the weight of the tillage implement **10**. In the illustrated embodiment, each wheel frame is pivotally coupled to the implement frame **14**, thereby facilitating adjustment of the vertical position of the respective wheel (s). However, in other embodiments, at least one wheel frame may be movably coupled to the implement frame by another suitable connection (e.g., sliding connection, linkage assembly, etc.) that facilitates adjustment of the vertical position of the respective wheel(s).

[0013] In the illustrated embodiment, the tillage implement **10** includes disc blades **32** configured to engage a top layer of the soil. As the tillage implement **10** is towed through the field, the disc blades **32** are driven to rotate, thereby breaking up the top layer of the soil. In the illustrated embodiment, the disc blades **32** are arranged in two rows. However, in other embodiments, the disc blades may be arranged in more or fewer rows (e.g., 1, 3, 4, 5, 6, or more). Furthermore, in the illustrated embodiment, each row of disc blades **32** includes four gangs of disc blades **32**. Two gangs of disc blades of the front row are coupled to the center section **18**, two gangs of disc blades of the rear row are coupled to the center section **18**, one gang of disc blades of the front row is coupled to the left wing section **20**, one gang of disc blades of the rear row is coupled to the left wing section **20**, one gang of disc blades of the front row is coupled to the right wing section **22**, and one gang of disc blades of the rear row is coupled to the right wing section **22**. While the tillage implement **10** includes eight gangs of disc blades **32** in the illustrated embodiment, in other embodiments, the tillage implement may include more or fewer gangs of disc blades (e.g., 2, 4, 6, 10, or more). Furthermore, the gangs of disc blades may be arranged in any suitable configuration on the implement frame.

[0014] The disc blades **32** of each gang are non-rotatably coupled to one another by a respective shaft, such that the disc blades **32** of each gang rotate together. Each shaft is rotatably coupled to a respective disc blade support **34**, which is configured to support the gang, including the shaft and the disc blades **32**. Furthermore, each disc blade support **34** is pivotally coupled to the frame **14** at a respective pivot point, thereby enabling the disc blade support **34** to rotate relative to the frame **14**. Rotating the disc blade support **34** relative to the frame **14** controls the angle between the respective disc blades **32** and the direction of travel **28**, thereby controlling the interaction of the disc blades **32** with the top layer of the soil. Each disc blade support **34** may include any suitable structure(s) configured to support the respective gang (e.g., including a square tube, a round tube, a bar, a truss, other suitable structure(s), or a combination thereof). While the disc blades **32** supported by each disc blade support **34** are arranged in a respective gang (e.g., non-rotatably coupled to one another by a respective shaft) in the illustrated embodiment, in other embodiments, at least a portion of the disc blades supported by at least one disc blade support (e.g., all of the disc blades supported by the disc blade support) may be arranged in another suitable configuration (e.g., individually mounted and independently rotatable, mounted in groups and individually rotatable, etc.). For example, in certain embodiments, a first portion of the disc blades supported by a disc blade support may be arranged in a gang, and a second portion of the disc blades supported by the disc blade support may be individually mounted and independently rotatable.

[0015] While the tillage implement includes the disc blades **32** in the illustrated embodiment, in other embodiments, the tillage implement may include other/additional ground engaging tool(s) (e.g., coupled to the disc blade support(s), coupled to the frame of the tillage implement, etc.). For example, in certain embodiments, the tillage implement may include tillage point assemblies (e.g., positioned behind the disc blades relative to the direction of travel) configured to engage the soil at a greater depth than the disc blades, thereby breaking up a lower layer of the soil. Each tillage point assembly may include a tillage point and a shank. The shank may position the tillage point at a target depth beneath the soil surface, and the tillage point may break up the soil. The shape of each tillage point, the arrangement of the tillage point assemblies, and the number of tillage point assemblies may be selected to control tillage within the field. Furthermore, in certain embodiments, the tillage implement may include finishing discs (e.g., positioned behind the disc blades relative to the direction of travel). In such embodiments, as the tillage implement is towed through the field, the finishing discs may be driven to rotate, thereby sizing soil clods, leveling the soil surface, smoothing the soil surface, cutting residue on the soil surface, or a combination thereof. In addition, in certain embodiments, the tillage implement may include one or more other/additional suitable ground engaging tools, such as coulter(s), opener(s), tine(s), finishing reel(s), other suitable ground engaging tool(s), or a combination thereof.

[0016] In the illustrated embodiment, the wing force management system **12** controls downforce applied to the left wing section **20** and to the right wing section **22** of the tillage implement **10** by wing fold cylinders. As discussed in detail below, the wing force management system **12** includes a hydromechanical linkage assembly coupled to the frame **14** of the tillage implement **10**. The hydromechanical linkage assembly includes a blocking valve and a link. The blocking valve is part of a hydraulic circuit configured to control the wing fold cylinders. For example, the hydraulic circuit may control left wing fold cylinders **36** (e.g., one or more left wing fold cylinders) to rotate the left wing section **20**, and the hydraulic circuit may control right wing fold cylinders **38** (e.g., one or more right wing fold cylinders) to rotate the right wing section **22**. The link is configured to actuate the blocking valve to drive the blocking valve to change positions (e.g., open to closed). A driver mounted to a wing section of the frame **14** is configured to drive the link to actuate the blocking valve while the tillage implement **10** is transitioning from a transport configuration, in which the wing sections are in the transport position, to a working configuration, in which the wing sections are in the working position. In certain embodiments, the link may be omitted from the hydromechanical linkage assembly, and the driver may directly engage the blocking valve to actuate the blocking valve.

[0017] The hydromechanical linkage assembly may have a transport mode and an operation mode. The hydromechanical linkage assembly may change modes when a wing section is at a particular orientation between the working position and the transport position. In the transport mode, the blocking valve is closed, and fluid in a portion of the hydraulic circuit may not drain, which may generate and maintain a high pressure in the portion of the hydraulic circuit, thereby deactivating a pressure reducing valve. As a result, high pressure may be applied to the wing lift cylinders, thereby enabling the wing sections to rotate downwardly toward the working position in a short timeframe. With the wing sections in the folded transport position, the wings sections may be angled inwardly. The high pressure applied to the wing fold cylinders causes the wing fold cylinders to drive the wing sections to rotate toward the working position until the blocking valve opens. The blocking valve may be actuated after the wing sections go over-center, as the force of gravity may help rotate the wing sections to the working position after the wing sections go over-center. Accordingly, high pressure is no longer applied to the wing fold cylinders to drive the wing sections to the working position. In the operation mode, the blocking valve is open, and fluid in the portion of the hydraulic circuit may drain, thereby enabling the pressure reducing valve to limit pressure within the wing fold cylinders. Therefore, the wing fold cylinders may apply a relatively small force to the wing sections of the tillage implement **10** (e.g., relative to the force applied by the wing lift cylinders to drive the wing sections toward the working position), thereby increasing the penetration depths of the ground-engaging tools (e.g., disc blades **32**). Limiting pressure within the wing fold cylinders in the operation mode may reduce compaction of the soil by the wheels while increasing the penetration depths of the ground-engaging tools. Accordingly, the wing force management system **12** may improve operation of the tillage implement **10** during transport and during tillage operations. While the wing force management system **12** is disclosed herein with regard to a tillage implement, the wing force management system may be employed within any suitable agricultural implement having rotatable wings, such as a planting implement, a seeding implement, a mowing implement, etc.

[0018] FIG. **2** is a schematic view of an embodiment of a wing force management system **12** that may be employed within the agricultural implement **10** of FIG. **1**. The wing force management system **12** includes a hydromechanical linkage assembly **50** coupled to the frame **14** of the tillage implement **10**. The hydromechanical linkage assembly **50** may be coupled to the frame **14** via any suitable type(s) of connection(s), such as a welded connection, a fastener connection, an adhesive connection, other suitable type(s) of connection(s), or a combination thereof. In the illustrated embodiment, the hydromechanical linkage assembly **50** is coupled to the center section **18** of the frame **14** via fasteners **52**. While only one hydromechanical linkage assembly is illustrated in FIG. **2**, the wing force management system **12** may include a left hydromechanical linkage assembly and a right hydromechanical linkage assembly. The left hydromechanical linkage assembly may be coupled to a left side of the center section **18** of the frame **14**, in proximity to a pivot joint between the center section **18** and the left wing section. The right hydromechanical linkage assembly may be coupled to a right side of the center section **18**, in proximity to a pivot joint between the center section **18** and the right wing section.

[0019] The hydromechanical linkage assembly **50** includes a blocking valve **54** and a link **56**. The blocking valve **54** and the link **56** may be coupled to a housing **58**, which may in turn be coupled to the frame **14** of the tillage implement **10** (e.g., via the fasteners **52**). The housing **58** may be made out of any suitable material (sheet metal, hard plastic, etc.) and may be any suitable shape to accommodate the blocking valve **54** and the link **56**. The housing **58** may protect the blocking valve **54** and the link **56** from debris (e.g., dirt, grass, etc.) and natural elements (rain, wind, etc.). While only one side of the housing **58** is shown in FIG. **2**, the housing may include multiple sides, including a rear side and a front side.

[0020] The blocking valve **54** may be a normally closed, spring return valve. That is, the blocking valve **54** may be closed unless acted upon (e.g., given a mechanical input), and a spring may return the valve back to, or maintain, the normally closed position. The link **56** may engage the blocking valve **54** to drive the blocking valve **54** open. A driver **60** is coupled to a wing section of the frame **14** (e.g., left wing section **20**) via a support **62** and is configured to drive the link **56** to actuate the blocking valve **54**. For example, when the wing section of the frame **14** rotates downwardly from the folded transport position to the unfolded working position, the driver **60** may drive the link **56** to drive the blocking valve **54** to the open position. Conversely, when the wing section of the frame **14** rotates upwardly from the working position to the transport position, the driver **60** may stop driving the link **56** to actuate the blocking valve **54**, thereby enabling the blocking valve to close. In certain embodiments, the link may be omitted and the driver may directly engage the blocking valve to actuate the blocking valve.

[0021] In the illustrated embodiment, the driver **60** includes a cam **64** that is configured to engage the link **56** while the wing section is at a particular orientation range between the transport position and the working position. This orientation range may be selected based on the configuration of the cam **64** and may depend on the use of the tillage implement **10**. For example, if the wing section has a typical working range between 0 degrees and 15 degrees above horizontal (e.g., the wing section of the tillage implement is positioned at an angle between 0 and 15 degrees relative to a horizontal plane during tillage operations), the cam **64** may be configured to engage the link **56** while the wing section of the tillage implement is positioned approximately between 0 and 45 degrees above horizontal, between 0 and 30 degrees above horizontal, or between 0 and 15 degrees above horizontal. The maximum angle of the orientation range may be less than 90 degrees, so the cam does not engage the link until the wing sections go over-center, as the force of gravity may help rotate the wing sections to the working position after the wing sections go over-center.

[0022] In the present embodiment, when the cam **64** engages the link **56**, the link **56** drives the blocking valve **54** open, such that the hydromechanical linkage assembly **50** is in the operation mode. Additionally, when the cam **64** does not engage (e.g., contact) the link **56**, the link **56** does not actuate the blocking valve **54**, such that the blocking valve **54** is closed, and the linkage assembly is in the transport mode. While the discussions herein have focused on a normally closed blocking valve **54**, the blocking valve **54** may be a normally opened, spring return valve. In such embodiments, the cam **64** may engage the link **56** to drive the link **56** to drive the blocking valve **54** to the closed position. Therefore, in embodiments with a normally open blocking valve **54**, when the cam **64** engages the link **56**, the link **56** drives the blocking valve **54** to the closed position, such that the hydromechanical linkage assembly **50** is in the transport mode. Additionally, in embodiments with a normally open blocking valve **54**, when the cam **64** does not engage the link **56**, the link **56** does not actuate the blocking valve **54**, such that the blocking valve **54** is open, and the hydromechanical linkage assembly **50** is in the operation mode.

[0023] The blocking valve **54** is part of a hydraulic circuit **70**. As discussed in detail below regarding FIG. **3**, the hydraulic circuit **70** is fluidly coupled to the left wing fold cylinders **36** and to the right wing fold cylinders **38** of the tillage implement **10**. The hydraulic circuit **70** may include a number of valves, and may control hydraulic fluid pressure within the left wing fold cylinders **36** and to the right wing fold cylinders **38** by controlling certain valves. In the illustrated embodiment, a controller **72** of a control system

74 is communicatively coupled to the hydraulic circuit **70** and is configured to output control signal(s) to certain valve(s) of the hydraulic circuit **70**. For example, a valve in the hydraulic circuit **70** may be configured to adjust fluid pressure within the left wing fold cylinders **36** and within the right wing fold cylinders **38** to control the downforce applied by the wing fold cylinders while each wing section is in the working position based on output control signal(s) from the controller **72**. Accordingly, the controller **72** is configured to control the left wing fold cylinders **36** and the right wing fold cylinders **38** via the hydraulic circuit **70**.

[0024] In the transport mode, the blocking valve **54** is closed, and fluid in a portion of the hydraulic circuit **70** may not drain, which may generate and maintain a high pressure in the portion of the hydraulic circuit **70**, thereby deactivating a pressure reducing valve. Therefore, the controller **72** may control the hydraulic circuit **70** to apply high pressure to the left wing fold cylinders **36** and the right wing fold cylinders **38**, enabling the wing sections to rotate downwardly toward the working position in short timeframe. In the operation mode, the blocking valve **54** is open, and fluid in a portion of the hydraulic circuit **70** may drain, thereby enabling the pressure reducing valve to limit pressure within the left wing fold cylinders **36** and the right wing fold cylinders **38**. Therefore, the controller **72** may control the hydraulic circuit **70** to apply relatively small force to the wing sections (e.g., relative to the force applied by the wing lift cylinders to drive the wing sections toward the working position), thereby increasing the penetration depths of the ground-engaging tools (e.g., disc blades). Limiting pressure within the wing fold cylinders in the operation mode may reduce compaction of the soil by the wheels while increasing the penetration depths of the ground-engaging tools.

[0025] The controller **72** is configured to control the left wing fold cylinders **36** and the right wing fold cylinders **38** to control the downforce applied by the ground-engaging tools (e.g., disc blades) while the tillage implement is in the working configuration. In certain embodiments, the controller **72** is an electronic controller having electrical circuitry configured to control the left wing fold cylinders **36** and the right wing fold cylinders **38** while the agricultural implement is in the working configuration. In the illustrated embodiment, the controller **72** includes a memory **76** and a processor **78**. The controller **72** may also include one or more storage devices and/or other suitable components. The processor **78** may be used to execute software, such as software for controlling the left wing fold cylinders **36** and the right wing fold cylinders **38**. Moreover, the processor **78** may include multiple microprocessors, one or more "general-purpose" microprocessors, one or more special-purpose microprocessors, and/or one or more application specific integrated circuits (ASICs), or some combination thereof. For example, the processor **78** may include one or more reduced instruction set (RISC) processors.

[0026] The memory **76** may include a volatile memory, such as random access memory (RAM), and/or a nonvolatile memory, such as read-only memory (ROM). The memory **76** may store a variety of information and may be used for various purposes. For example, the memory **76** may store processor-executable instructions (e.g., firmware or software) for the processor **78** to execute, such as instructions for controlling the left wing fold cylinders **36** and the right wing fold cylinders **38**. The storage device(s) (e.g., nonvolatile storage) may include ROM, flash memory, a hard drive, or any other suitable optical, magnetic, or solid-state storage medium, or a combination thereof. The storage device(s) may store data, instructions (e.g., software or firmware for controlling the left wing fold cylinders **36** and the right wing fold cylinders **38**), and any other suitable data.

[0027] In some embodiments, the controller **72** may control the left wing fold cylinders **36** and the right wing fold cylinders **38** based on sensor feedback. For example, the hydraulic circuit **70** may include one or more sensors **80**. The sensor(s) **80** may include a pressure sensor, a position sensor, a penetration depth sensor, and the like. For example, a pressure sensor may be fluidly coupled to the left wing fold cylinders **36** and to the right wing fold cylinders **38**. The pressure sensor may output a signal indicative of a fluid pressure within the left wing fold cylinders **36** and within the right wing fold cylinders **38**. Accordingly, the controller **72** may control the left wing fold cylinders **36** and the right wing fold cylinders **38** based on feedback from the pressure sensor to control the downforce applied by the wing fold cylinders while the tillage implement is in the working configuration.

[0028] Additionally and/or alternatively, a pressure sensor may be coupled to a fluid conduit of the hydraulic circuit **70** and may output a signal indicative of a pilot pressure within the hydraulic circuit **70**. The pilot pressure may indicate whether the hydromechanical linkage assembly **50** is in the transport mode (e.g., associated with a high pilot pressure) or in the operation mode (e.g., associated with a low pilot pressure). Accordingly, the controller **72** may use pilot pressure sensor feedback to determine whether the hydromechanical linkage assembly **50** is in the transport mode or the operation mode.

[0029] Additionally and/or alternatively, a position sensor may be coupled to a left wing fold cylinder **36**, to a right wing fold cylinder **38**, to the left wing section **20**, to the right wing section **22**, to another suitable component of the tillage implement **10**, or a combination thereof. The position sensor may output a signal indicative of the angular position of the left wing section **20** and/or the right wing section **22** relative to the center section **18**. Accordingly, the controller **72** may determine the angular position(s) of the left wing section **20** and/or the right wing section **22** based on feedback from the position sensor(s).

[0030] Additionally and/or alternatively, a depth sensor may be coupled to any suitable component of the tillage implement (e.g., left wing section **20**, right wing section, etc.), and the depth sensor may output a signal indicative of the penetration depth of the ground-engaging tools (e.g., disc blades). Accordingly, the controller **72** may control the hydraulic circuit **70** to adjust the downforce applied by the left wing fold cylinders **36** and the right wing fold cylinders **38** based on feedback from the depth sensor(s) to adjust the penetration depth of the ground-engaging tools.

[0031] In the illustrated embodiment, the control system **74** includes a user interface **82** communicatively coupled to the controller **72**. The user interface **82** is configured to receive input from an operator and to provide information to the operator (e.g., hydraulic fluid pressure and/or flow, wing section position, etc.). The user interface **82** may include any suitable input device(s) for receiving input, such as a keyboard, a mouse, button(s), switch(es), knob(s), other suitable input device(s), or a combination thereof. In addition, the user interface **82** may include any suitable output device(s) for presenting information to the operator, such as speaker (s), indicator light(s), other suitable output device(s), or a combination thereof. In the illustrated embodiment, the user interface **82** includes a display **84** configured to present visual information to the operator (e.g., real time/near real time information, such as hydraulic fluid pressure and/or flow, wing section position, etc.). In certain embodiments, the display **84** may include a touchscreen interface configured to receive input from the operator (e.g., a capacitive touch screen with haptic feedback).

[0032] In certain embodiments, the user interface **82** is configured to receive input from the operator indicative of a command to increase or decrease the downforce applied by the left wing fold cylinders **36** and/or the right wing fold cylinders **38**. The controller **72** is configured to control the left wing fold cylinders **36** and the right wing fold cylinders **38** based on the command. For example, in response to an indication on the user interface **82** that the penetration depth is less than a target penetration depth, the operator may provide an input to the user interface **82** indicative of increasing the downforce applied by the left wing fold cylinders **36** and/or the right wing fold cylinders **38**.

[0033] FIG. **3** is a schematic diagram of an embodiment of a hydraulic circuit **70** that may be employed within the wing force management system of FIG. **2**. The hydraulic circuit **70** is fluidly coupled to the left wing fold cylinders **36** and to the right wing fold cylinders **38** of the tillage implement. The hydraulic circuit **70** includes a first hydraulic fluid input **100** and a second hydraulic fluid input **102**. The first hydraulic fluid input **100** is configured to provide hydraulic fluid for extension of the left wing fold cylinders **36** and the right wing fold cylinders **38**. The second hydraulic fluid input **102** is configured to provide hydraulic fluid for retraction of the left wing fold cylinders **36** and the right wing fold cylinders **38**. In certain embodiments, the controller of FIG. **2** may control the hydraulic fluid flow into the first and second hydraulic fluid inputs.

[0034] The second hydraulic fluid input **102** is directly fluidly coupled to the rod ends of the left wing fold cylinders **36** and the right wing fold cylinders **38**. Accordingly, fluid may be provided to the second hydraulic fluid input **102** to directly control retraction of the wing fold cylinders, without intermediate valves. Furthermore, the first hydraulic fluid input **100** is fluidly coupled to the cap ends of the left wing fold cylinders **36** and the right wing fold cylinders **38** via a valve assembly **104**. Therefore, when fluid is provided to the first hydraulic fluid input **100**, the valve assembly **104** may control extension of the left wing fold cylinders **36** and the right wing fold cylinders **38**. For example, the valve assembly **104** may control the fluid pressure within the cap ends of the left wing fold cylinders **36** and the right wing fold cylinders **38** to adjust the penetration depth of the ground-engaging tools. The valve assembly **104** is fluidly coupled to a left wing blocking valve **54'** and to a right wing blocking valve **54"**. The hydromechanical linkage assembly **50** of FIG. **2** may include the left wing blocking valve **54'** and the right wing blocking valve **54"**, each function as the blocking valve **54** disclosed above. When the left wing blocking valve **54'** or the right wing blocking valve **54"** is closed in the transport mode of the hydromechanical linkage assembly **50**, the hydraulic fluid in a portion of the valve assembly **104** does not drain, thereby deactivating a pressure reducing valve. Accordingly, fluid applied to the first hydraulic fluid input **100** may directly flow to the cap ends of the wing fold cylinders, thereby enabling direct control of extension of the wing fold cylinders via the first hydraulic fluid input **100**.

[0035] As depicted, the hydraulic circuit **70** is fluidly coupled to a hydraulic system **106** of a work vehicle (e.g., tractor) coupled to the tillage implement. The hydraulic system **106** of the work vehicle may provide pressurized hydraulic fluid to the hydraulic circuit **70** via a supply line **108** (e.g., high pressure supply line). Hydraulic fluid is returned to the hydraulic system **106** from the hydraulic circuit **70** via a return line **110** (e.g., a low pressure return line). In certain embodiments, there may be multiple supply lines **108** and/or multiple return lines **110** extending between the hydraulic circuit **70** and the hydraulic system **106** of the work vehicle.

[0036] The hydraulic system **106** includes a supply pump **112** located on the work vehicle. The supply pump **112** is configured to receive hydraulic fluid from a fluid source (e.g., tank) and to provide the fluid to the valve assembly **104** via the supply line **108**. The valve assembly **104** includes a first check valve **114** in fluid communication with the supply line **108**. The first check valve **114** is configured to enable flow of the hydraulic fluid from the supply pump **112** to downstream components of the valve assembly **104** and to block flow of the hydraulic fluid from the downstream components into the supply line **108**. The hydraulic system **106** also includes a return **116** located on the work vehicle. The return **116** is configured to receive hydraulic fluid from the valve assembly **104** via the return line **110**.

[0037] The valve assembly **104** also includes a first directional control valve **118**, which is fluidly coupled to the supply line **108** via the first check valve **114**. The first directional control valve **118** is a three-way, two-position directional control valve that is fluidly coupled to the supply line **108** and to a first control line **120**, which is fluidly coupled to the first hydraulic fluid input **100**. In a first position, the first directional control valve **118** enables hydraulic fluid to flow through the conduits between the first hydraulic fluid input **100** and the cap ends of the left wing fold cylinders **36** and the right wing fold cylinders **38**. Furthermore, the valve assembly **104** includes a second check valve **122** fluidly coupled to the first directional control valve **118**. The second check valve **122** is configured to enable hydraulic fluid flow from the cap ends of the left wing fold cylinders **36** and the right wing fold cylinders **38** to the first hydraulic fluid input **100** while the first directional control valve **118** is in the illustrated first position, thereby enabling hydraulic fluid from the cap ends of the left wing fold cylinders **36** and the right wing fold cylinders **38** to drain to the first hydraulic fluid input **100** while the wing fold cylinders are retracting. The second check valve **122** is also configured to block hydraulic fluid flow through the second check valve **122** while hydraulic fluid is supplied to the cap ends of the wing fold cylinders.

[0038] Furthermore, the valve assembly **104** includes a pressure reducing valve **124**, which is fluidly coupled to the first directional control valve **118**. The pressure reducing valve **124** is also fluidly coupled to the cap ends of the wing fold cylinders via a cap end conduit **125**. The pressure reducing valve **124** is configured to selectively reduce the pressure of the hydraulic fluid supplied to the cap ends of the left wing fold cylinders **36** and the right wing fold cylinders **38**, thereby controlling the downforce applied by the wing fold cylinders. In addition, the valve assembly **104** includes a first pressure relieving valve **126** fluidly coupled to the cap end conduit **125** at a location downstream from the pressure reducing valve **124**. The first pressure relieving valve **126** is configured to direct hydraulic fluid from the cap end conduit **125** to the return line **110** in response to the fluid pressure within the cap end conduit **125** exceeding a maximum threshold pressure, thereby limiting the fluid pressure within the cap ends of the wing fold cylinders to the maximum threshold pressure. The maximum threshold pressure is controlled by fluid pressure within a pilot line **128** (represented as dashed a line in FIG. **3**), which is fluidly coupled to the first pressure relieving valve **126**. Control of the fluid pressure within the pilot line **128** is disclosed in detail below.

[0039] An orifice **130** and a third check valve **132** are disposed between the cap end conduit **125** and the pilot line **128**. The orifice **130** is configured to regulate the flow of hydraulic fluid from the cap end conduit **125** to the pilot line **128**, and the third check valve **132** is configured to enable fluid flow from the cap end conduit **125** to the pilot line **128** and to block fluid flow from the pilot line **128** to the cap end conduit **125**. Accordingly, the pilot line **128** is provided with hydraulic fluid from the cap end conduit **125**. A second pressure relieving valve **134** is fluidly coupled to the pilot line **128** and to the return line **110**. The second pressure relieving valve **134** is configured to direct hydraulic fluid from the pilot line **128** to the return line **110** in response to the fluid pressure within the pilot line **128** exceeding a maximum pilot threshold pressure, thereby limiting the fluid pressure within the pilot line **128** to the maximum pilot threshold pressure.

[0040] In the illustrated embodiment, the first directional control valve **118** is controlled by a second directional control valve **136**. The second directional control valve **136** is a three-way, two-position directional control valve that is fluidly coupled to a pilot pressure actuator of the first directional control valve **118**, to the supply line **108** downstream from the first check valve **114**, and to the return line **110**. In a first position, the second directional control valve **136** fluidly couples the pilot pressure actuator of the first directional control valve **118** to the return line **110**, thereby enabling the first directional control valve **118** to move to the first position. In a second position, the second directional control valve **136** fluidly couples the supply line **108** to the pilot pressure actuator of the first directional control valve **118**, thereby driving the first directional control valve **118** to the second position. The position of the second directional control valve **136** is controlled by a solenoid communicatively coupled to the controller. Accordingly, the controller is configured to control the position of the first directional control valve **118** via the second directional control valve **136**.

[0041] The left wing blocking valve **54'** and the right wing blocking valve **54"** are fluidly coupled to a pilot drain line **129**. Furthermore, a pilot pressure control valve **138** is fluidly coupled to the pilot line **128** and to the pilot drain line **129**. The pilot pressure control valve **138** is configured to control the hydraulic fluid pressure within the pilot line **128** by controlling hydraulic fluid flow from the pilot line **128** to the pilot drain line **129**. In the illustrated embodiment, the controller is communicatively coupled to the pilot pressure control valve **138**, and the controller is configured to control the pilot pressure control valve **138** to control the fluid pressure within the pilot line **128**. As illustrated, the pilot drain line **129** is fluidly coupled to the return line **110**. In addition, a fourth check valve **140** is fluidly coupled to the pilot drain line **129** upstream of the blocking valves **54**. The fourth check valve **140** is configured to enable hydraulic fluid to flow from the pilot pressure control valve **138** through the pilot drain line **129** and to block hydraulic fluid flow from the pilot drain line **129** to the pilot line **128**.

[0042] When the hydromechanical linkage assembly **50** is in the transport mode, the left wing blocking valve **54'** and the right wing blocking valve **54"** are closed. When either of the left wing blocking valve **54'** or the right wing blocking valve **54"** is closed, the pilot drain line **129** is blocked, thereby blocking hydraulic fluid flow from the pilot line **128** to the return line **110**. As a result, the hydraulic fluid pressure within the pilot line **128** may increase to the maximum pilot threshold pressure because the pilot pressure control valve **138** is unable to drain hydraulic fluid through the pilot drain line **129**. Accordingly, the pressure reducing valve **124**, which is controlled by the hydraulic fluid pressure within the pilot line **128**, is driven to the fully open position. As such, when the left wing blocking valve **54'** and/or the right wing blocking valve **54"** are closed, fluid provided to valve assembly **104** (e.g., from the first hydraulic fluid input **100**) directly controls extension of the wing fold cylinders. In certain embodiments, when the blocking valve(s) are closed, the controller controls the second directional control valve **136** to move to the first position to enable the first directional control valve **118** to move to the first position, thereby enabling the first hydraulic fluid input **100** to provide fluid to the valve assembly **104**.

[0043] Conversely, when the hydromechanical linkage assembly **50** is in the operation mode, the left wing blocking valve **54'** and the right wing blocking valve **54"** are open. When the left wing blocking valve **54'** and the right wing blocking valve **54"** are open, hydraulic fluid from the pilot line **128** may drain through the pilot drain line **129**, thereby enabling the pilot pressure control valve **138** to control the hydraulic fluid pressure within the pilot line **128**. Because the hydraulic fluid pressure within the pilot line **128** controls the pressure reducing valve **124**, the controller may control the pilot pressure control valve **138** to control the pressure reducing valve **124**, thereby controlling the hydraulic fluid pressure within the cap ends of the wing fold cylinders. As such, when the left wing blocking valve **54'** and the right wing blocking valve **54"** are open, the controller controls the pilot pressure control valve **138** to control the hydraulic fluid pressure within the cap ends of the wing fold cylinders. Therefore, the controller controls the downforce applied by the wing fold cylinders. In certain embodiments, when the blocking valves are open, the controller also controls the second directional control valve **136** to move to the second position to drive the first directional control valve **118** to the second position, such that the supply pump **112** provides hydraulic fluid to the valve assembly **104**. Furthermore, as previously discussed, the controller may control the downforce applied by the wing fold cylinders based on feedback from the sensors (e.g., position sensor(s), penetration depth sensor(s), etc.). In addition, in certain embodiments, pressure sensor(s) **142** fluidly coupled to the pilot line **128** may enable the controller to determine whether the hydromechanical linkage assembly **50** is in the transport or the operation mode based on sensor feedback.

[0044] The second hydraulic fluid input **102** is directly fluidly coupled to the rod ends of the left wing fold cylinders **36** and the right wing fold cylinders **38** via a second control line **144**. Accordingly, to drive the wing fold cylinders to retract, the controller may control the second directional control valve **136** to move to the first position to enable the first directional control valve **118** to move to the first position, such that hydraulic fluid may drain through the first hydraulic fluid input **100**. Hydraulic fluid from the second hydraulic fluid input **102** may then be provided to the rod ends of the wing fold cylinders to drive the wing fold cylinders to retract, regardless of the configuration of the blocking valves **54**.

[0045] While the first directional control valve **118** is controlled by the second directional control valve **136** in the illustrated embodiment, in other embodiments, the second directional control valve may be omitted, and the controller may control the first directional control valve directly. Moreover, in certain embodiments, the tillage implement may include two hydraulic circuits, one for the left wing fold cylinders and one for the right wing fold cylinders, thereby enabling independent control of the left wing section and the right wing section of the tillage implement. In such embodiments, each hydraulic circuit may include one respective blocking valve.

[0046] While only certain features have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the disclosure.

[0047] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for (perform)ing (a function) . . . " or "step for (perform)ing (a function) . . . ", it is intended that such elements are to be interpreted under 35 U.S.C. 112 (f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

1. A wing force management system of an agricultural implement, comprising:
- a hydromechanical linkage assembly configured to couple to a frame of the agricultural implement, wherein the hydromechanical linkage assembly comprises a blocking valve;
- a driver coupled to the frame of the agricultural implement; and
- a valve assembly configured to control a wing fold cylinder of the agricultural implement, wherein the wing fold cylinder is configured to drive a wing section of the frame to rotate relative to a center section of the frame, and the valve assembly is fluidly coupled to the blocking valve;
- wherein the driver is configured to actuate the blocking valve in response to rotation of the wing section of the frame to control the valve assembly to adjust fluid pressure within the wing fold cylinder.

2. The wing force management system of claim **1**, wherein the driver is configured to actuate the blocking valve in response to rotation of the wing section from a folded transport position toward an unfolded working position.

3. The wing force management system of claim **1**, wherein the hydromechanical linkage assembly comprises a link, and the driver is configured to engage the link to actuate the blocking valve.

4. The wing force management system of claim **1**, wherein the driver is configured to actuate the blocking valve while the wing section is positioned at an angle between 0 and 45 degrees relative to a horizontal plane.

5. The wing force management system of claim **1**, wherein the valve assembly is configured to control downforce applied by the wing fold cylinder while the blocking valve is open.

6. The wing force management system of claim **5**, comprising a controller comprising a memory and a processor, wherein the controller is configured to control the valve assembly to control the downforce applied by the wing fold cylinder.

7. The wing force management system of claim **6**, comprising a penetration depth sensor communicatively coupled to the controller, wherein the penetration depth sensor is configured to output a signal indicative of a penetration depth of one or more ground-engaging tools of the agricultural implement, and the controller is configured to control the valve assembly to control the downforce applied by the wing fold cylinder based on sensor feedback from the penetration depth sensor.

8. An agricultural implement, comprising:
- a frame comprising a center section and a wing section;
- one or more ground-engaging tools coupled to the frame;
- a wing fold cylinder coupled to the center section and to the wing section, wherein the wing fold cylinder is configured to control an angular position of the wing section relative to the center section;
- a hydraulic circuit comprising a valve assembly fluidly coupled to the wing fold cylinder, wherein the valve assembly is configured to control the wing fold cylinder;
- a hydromechanical linkage assembly coupled to the frame, wherein the hydromechanical linkage assembly comprises a blocking valve;
- a driver coupled to the frame;
- wherein the driver is configured to actuate the blocking valve in response to rotation of the wing section to control the valve assembly to adjust fluid pressure within the wing fold cylinder.

9. The agricultural implement of claim **8**, wherein the hydromechanical linkage assembly comprises a link, and the driver is configured to engage the link to actuate the blocking valve.

10. The agricultural implement of claim **9**, wherein the driver is configured to engage the link to actuate the blocking valve while the wing section is positioned at an angle between 0 and 45 degrees relative to a horizontal plane.

11. The agricultural implement of claim **8**, wherein the valve assembly is configured to control downforce applied by the wing fold cylinder while the blocking valve is open.

12. The agricultural implement of claim **11**, comprising a controller comprising a memory and a processor, wherein the controller is configured to control the valve assembly to control the downforce applied by the wing fold cylinder.

13. The agricultural implement of claim **12**, comprising a penetration depth sensor communicatively coupled to the controller, wherein the penetration depth sensor is configured to output a signal indicative of a penetration depth of the one or more ground-engaging tools, and the controller is configured to control the valve assembly to control the downforce applied by the wing force cylinder to adjust the penetration depth of the one or more ground-engaging tools.

14. The agricultural implement of claim **8**, comprising:

a second wing section of the frame;

a second wing fold cylinder coupled to the center section and to the second wing section, wherein the second wing fold cylinder is configured to control an angular position of the second wing section relative to the center section;

a second blocking valve of the hydromechanical linkage assembly; and

a second driver coupled to the frame, wherein the second driver is configured to actuate the second blocking valve in response to rotation of the second wing section to control the valve assembly to adjust fluid pressure within the second wing fold cylinder.

15. A hydraulic circuit of an agricultural implement, comprising:

a valve assembly comprising:

a pressure reducing valve configured to control downforce applied by a wing fold cylinder of the agricultural implement, wherein the wing fold cylinder is configured to drive a wing section of a frame of the agricultural implement to rotate relative to a center section of the frame of the agricultural implement;

a pilot line configured to control the pressure reducing valve; and

a blocking valve configured to control hydraulic fluid in the pilot line; and

a driver coupled to the frame of the agricultural implement, wherein the driver is configured to actuate the blocking valve in response to rotation of the wing section to control the valve assembly to adjust fluid pressure within the wing fold cylinder.

16. The hydraulic circuit of claim **15**, comprising:

a first hydraulic fluid input configured to fluidly couple to a cap end of the wing fold cylinder of the agricultural implement via the valve assembly, wherein the first hydraulic fluid input is configured to supply hydraulic fluid to the valve assembly to control extension of the wing fold cylinder; and

a second hydraulic fluid input configured to directly fluidly couple to a rod end of the wing fold cylinder of the agricultural implement, wherein the second hydraulic fluid input is configured to supply the hydraulic fluid to the rod end of the wing fold cylinder to control retraction of the wing fold cylinder

17. The hydraulic circuit of claim **15**, comprising:

a supply line configured to provide the hydraulic fluid from a supply pump to the valve assembly; and

a return line configured to provide the hydraulic fluid from the valve assembly to a return.

18. The hydraulic circuit of claim **17**, comprising a pilot pressure control valve fluidly coupled to the pilot line and to a pilot drain line, wherein the pilot drain line is fluidly coupled to the return line, the pilot pressure control valve is configured to control hydraulic fluid flow from the pilot line to the pilot drain line, and the blocking valve is fluidly coupled to the pilot drain line to control hydraulic fluid pressure in the pilot line.

19. The hydraulic circuit of claim **18**, wherein the agricultural implement comprises a controller comprising a memory and a processor, the controller is configured to control the pilot pressure control valve to control the pressure reducing valve to control the hydraulic fluid pressure within the wing fold cylinder to control the downforce applied by the wing fold cylinder while the blocking valve is open.

20. The hydraulic circuit of claim **15**, wherein the hydraulic fluid provided to the valve assembly directly controls the extension of the wing fold cylinder of the agricultural implement while the blocking valve is closed.

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