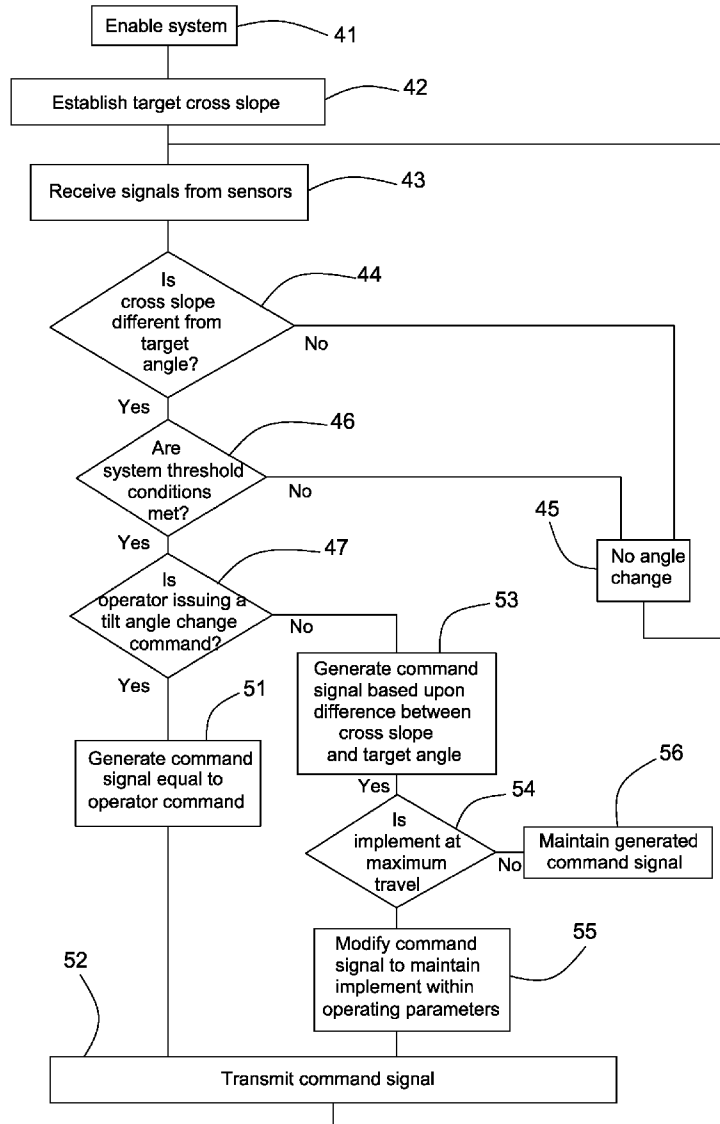




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Callaway(10) **Pub. No.: US 2013/0158819 A1**(43) **Pub. Date: Jun. 20, 2013**(54) **IMPLEMENT CONTROL SYSTEM FOR A MACHINE**(52) **U.S. Cl.**
USPC 701/50(75) Inventor: **Joshua Callaway**, Cary, NC (US)(57) **ABSTRACT**(73) Assignee: **CATERPILLAR INC.**, Peoria, IL (US)(21) Appl. No.: **13/332,024**(22) Filed: **Dec. 20, 2011****Publication Classification**(51) **Int. Cl.**
E02F 3/84 (2006.01)

A system for automated movement of a ground engaging blade of a machine includes an acceleration sensor and a roll rate sensor on the blade to indicate a cross slope angular position of the blade. A controller stores a target cross slope and compares the target cross slope to the cross slope angular position. Movement of the ground engaging blade is at least in part based upon a difference between the target cross slope and the cross slope angular position to maintain the ground engaging blade at the target cross slope.



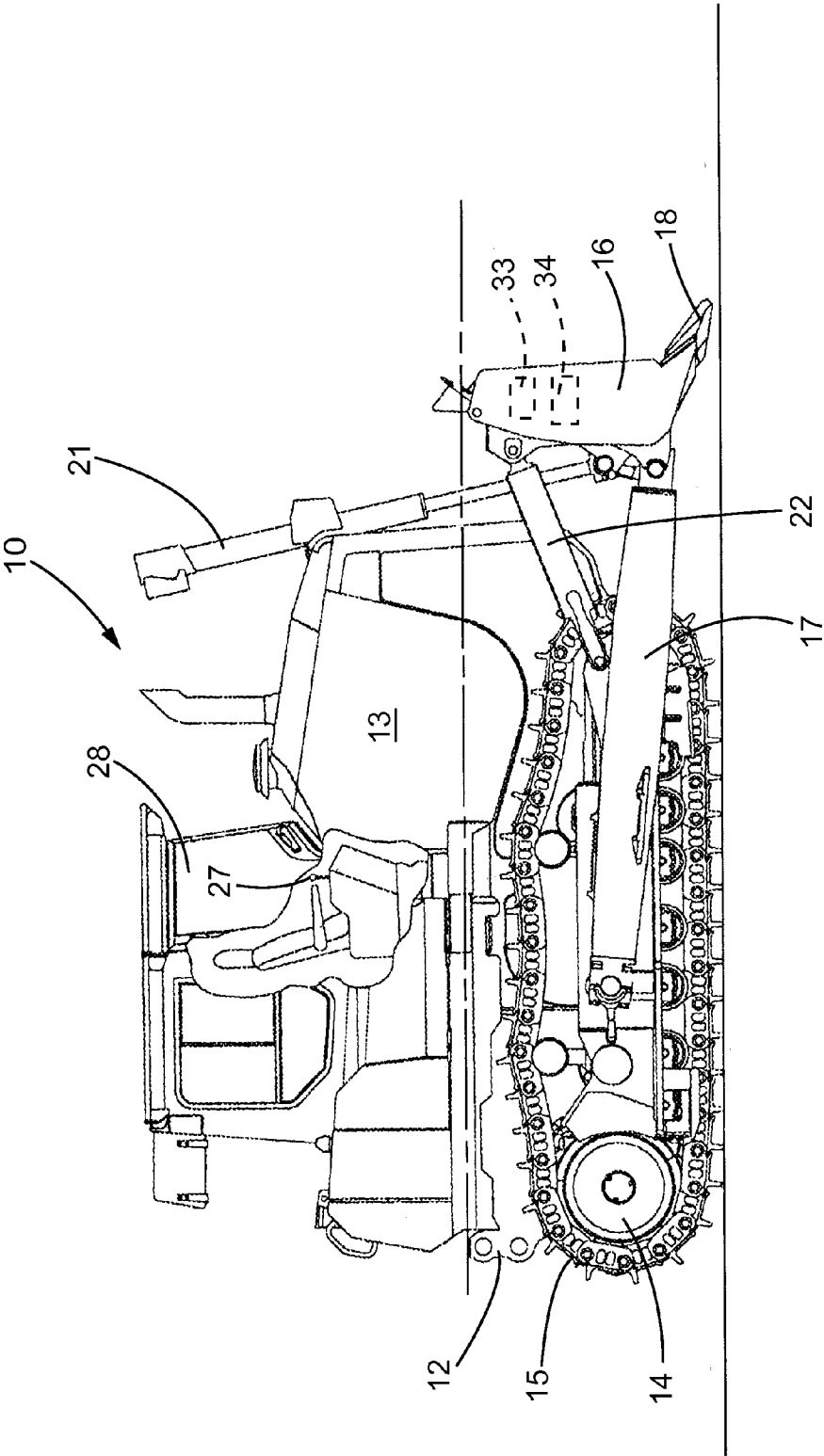


FIG. 1

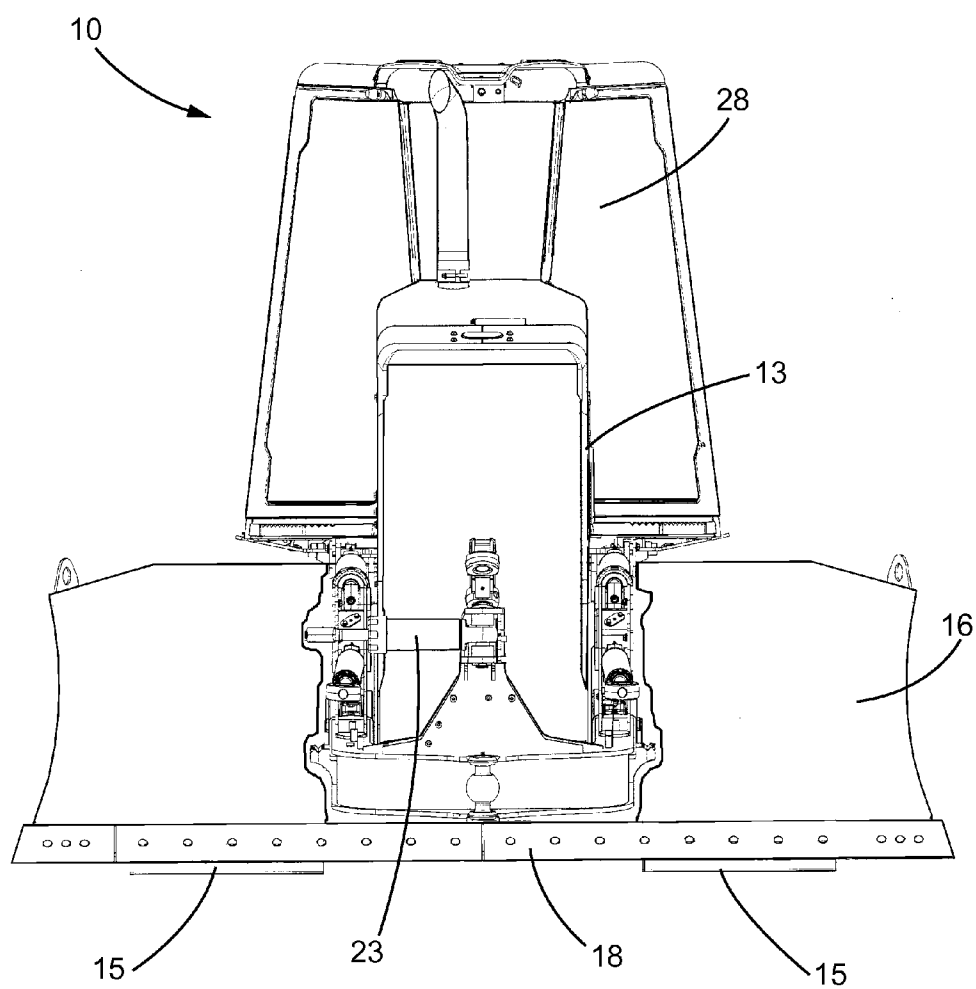
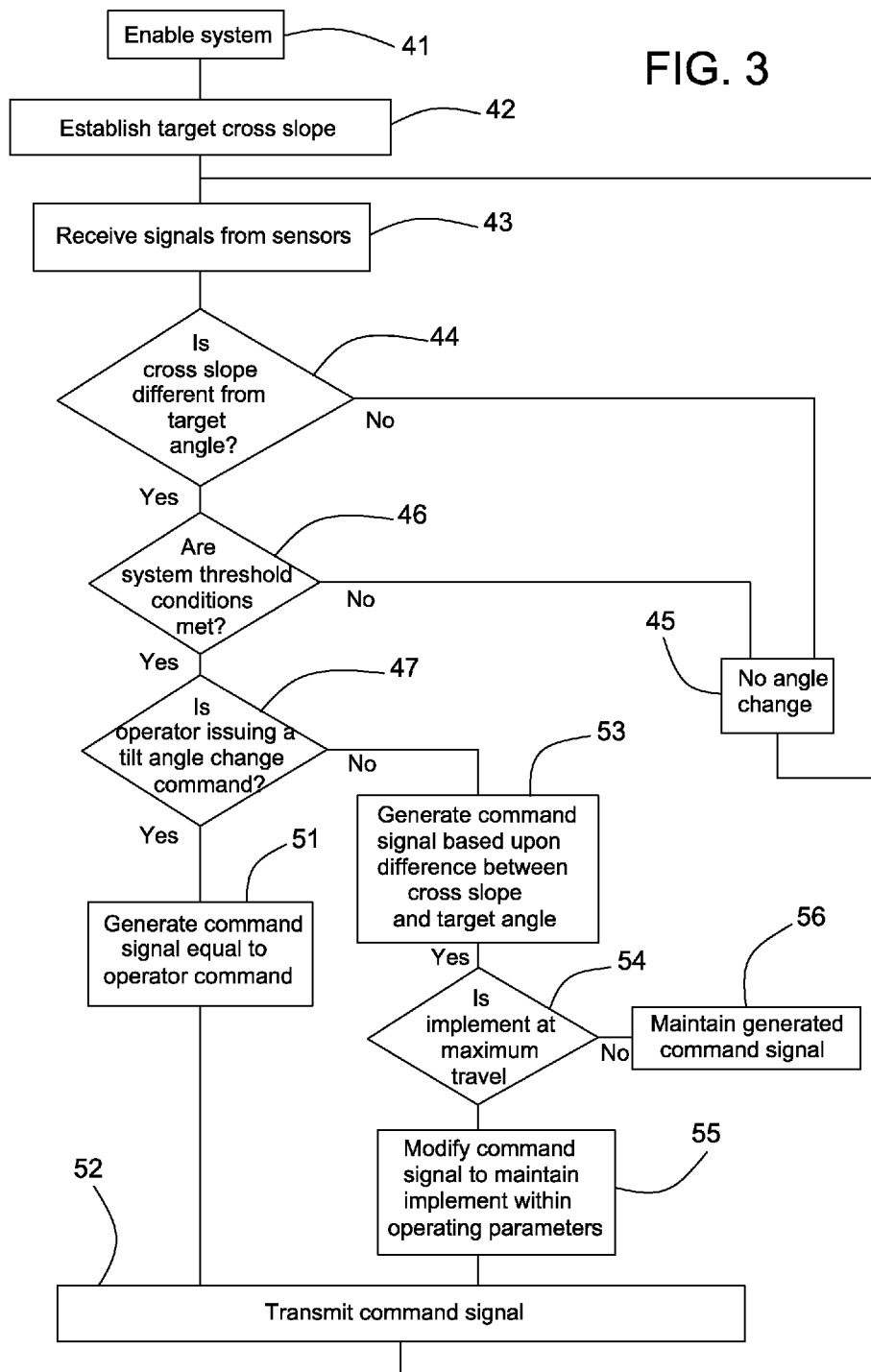


FIG. 2

FIG. 3



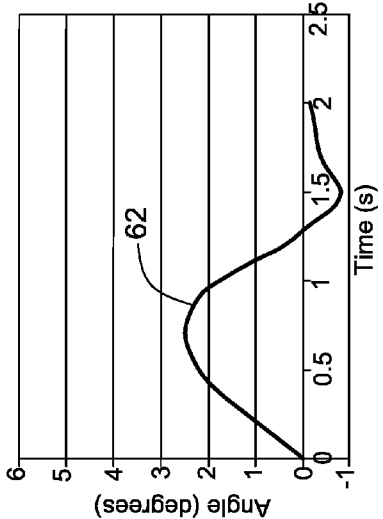


FIG. 5

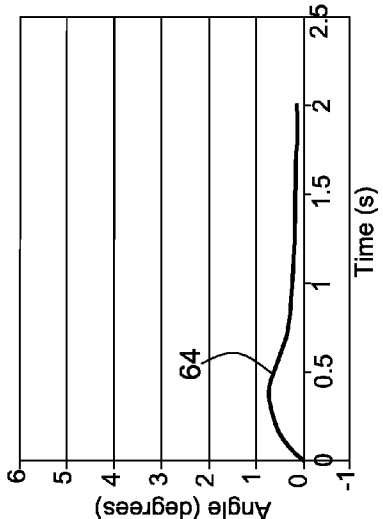


FIG. 7

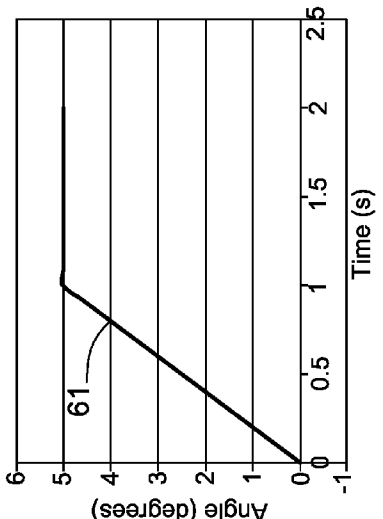


FIG. 4

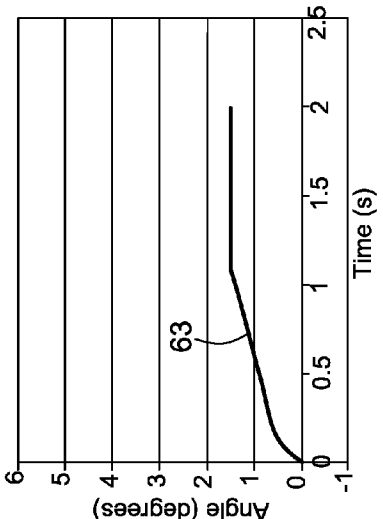


FIG. 6

IMPLEMENT CONTROL SYSTEM FOR A MACHINE

TECHNICAL FIELD

[0001] This disclosure relates generally to controlling an implement and, more particularly, to a system and method for controlling the cross slope of a ground engaging blade.

BACKGROUND

[0002] Machines such as a tractors, bulldozers and the like are often equipped with attached implements for performing various tasks. For example, a tractor may be equipped with a ground engaging blade for performing tasks such as scraping the ground and moving material in a controlled fashion. An operator may move the blade in various directions relative to the ground. This helps the tractor complete the task of properly leveling or contouring the ground on which the tractor is operating. This is a task often performed during the construction of roads, buildings, or other structures.

[0003] One difficulty when operating such a machine is maintaining a consistent position of the blade as the tractor moves over uneven terrain. Movement of the machine up and down and from side to side results in similar movements of the blade despite a desire to maintain the blade in a fixed orientation relative to a ground reference. As a result of such movement, the work surface created by the machine may be uneven and require additional work to create a desired work surface.

[0004] An operator of a machine may correct for uneven terrain by adjusting the motion of the blade as the machine moves to compensate for the machine's movement, resulting in a smoother surface. However, the quality of the resulting grade is dependent on the skill of the operator in anticipating the need to adjust the blade. The operator may, in addition or alternatively, slow the speed of the machine while adjusting the blade position in response to uneven terrain. Such operations tend to reduce efficiency and increase cost.

[0005] U.S. Pat. No. 7,121,355 to Lumpkins et. al ("Lumpkins") discloses a control system for controlling the position of a machine blade for grading. The control system determines the difference between a target position of the blade and its actual position, and generates a control signal calculated to move the blade to the target position.

[0006] The foregoing background discussion is intended solely to aid the reader. It is not intended to limit the innovations described herein, nor to limit or expand the prior art discussed. Thus, the foregoing discussion should not be taken to indicate that any particular element of a prior system is unsuitable for use with the innovations described herein, nor is it intended to indicate that any element is essential in implementing the innovations described herein. The implementations and application of the innovations described herein are defined by the appended claims.

SUMMARY

[0007] In one aspect, a control system is provided for controlling automated movement of a ground engaging blade of a machine. The ground engaging blade is configured for rotational movement about an axis to define a cross slope of the ground engaging blade. A first sensor is located on the ground engaging blade and configured to provide a measured cross slope signal indicative of a cross slope of the ground engaging blade. A second sensor is disposed on the ground engaging

blade configured to provide a roll rate signal indicative of a roll rate of the ground engaging blade. A controller is configured to store a target cross slope signal indicative of a target cross slope of the ground engaging blade, determine a cross slope angular position based upon the measured cross slope signal and the roll rate signal, and compare the target cross slope to the cross slope angular position. The controller further generates a command signal at least in part based upon a difference between the target cross slope and the cross slope angular position to control movement of the ground engaging blade by transmitting the command signal to control movement of the ground engaging blade. In this way, the ground engaging blade may be maintained at or near the target cross slope.

[0008] In another aspect, a controller implemented method of adjusting a ground engaging blade of a machine is provided. The ground engaging blade has a first sensor configured to provide a measured cross slope signal indicative of a cross slope of the ground engaging blade and second sensor configured to provide a roll rate signal indicative of a roll rate of the ground engaging blade. The method includes storing within a controller a target cross slope signal indicative of a target cross slope of the ground engaging blade, determining the cross slope angular position based upon the measured cross slope signal and the roll rate signal, and comparing the target cross slope to the cross slope angular position. The controller generates a command signal at least in part based upon a difference between the target cross slope and the cross slope angular position to control movement of the ground engaging blade and to maintain the ground engaging blade at the target cross slope. The command signal is transmitted from the controller to control movement of the ground engaging blade.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 shows a side view of a machine including a system in accordance with the disclosure;

[0010] FIG. 2 shows a front view of a machine similar to that of FIG. 1 with certain components removed and broken away for clarity;

[0011] FIG. 3 shows a flowchart illustrating a cross slope control process in accordance with the disclosure; and

[0012] FIG. 4 is an exemplary performance graph of the cross slope of a machine moving along a simulated path;

[0013] FIG. 5 is an exemplary performance graph of the cross slope of the ground engaging blade of the machine of FIG. 4 moving along the simulated path and after being corrected based upon a signal from a first sensor;

[0014] FIG. 6 is an exemplary performance graph of the cross slope of the ground engaging blade of the machine of FIG. 4 moving along the simulated path and after being corrected based upon a signal from a second sensor; and

[0015] FIG. 7 is an exemplary performance graph of the cross slope of the ground engaging blade of the machine of FIG. 4 moving along the simulated path and after being corrected based upon signals from the first sensor and the second sensor.

DETAILED DESCRIPTION

[0016] FIG. 1 shows a diagrammatic illustration of a machine that may be used in accordance with an embodiment of the disclosure. A machine 10 includes a frame 12 and a prime mover such as an engine 13. A pair of drive wheels (one

of which is illustrated as a drive wheel 14) are disposed on each side of machine 10 and operate to drive a pair of tracks (one of which is shown as a track 15) to propel machine 10. Although machine 10 is shown in a “track-type” configuration, other configurations, such as a wheeled configuration, may be used. In addition, the systems and methods of the disclosure may be used with any machine propulsion and drive train mechanisms applicable in the art. Further, the systems and methods disclosed herein may also be used on machines other than a tractor having a ground engaging blade, such as a loader or a motor grader.

[0017] Machine 10 includes an implement such as ground engaging blade 16 pivotally connected to frame 12 by a pair of opposed arm (one of which is illustrated as an arm 17) disposed on each side of machine 10. A lift hydraulic cylinder 21 is coupled to frame 12 and supports ground engaging blade 16 in the vertical direction, and allow ground engaging blade 16 to move up or down vertically from the point of view of FIG. 1. A pair of pitch hydraulic cylinders 22 on each side of machine 10 (FIG. 2) allow the pitch angle of blade tip 18 to change relative to an axis or centerline of the machine (“CL” in FIG. 1). Actuating the pitch hydraulic cylinders 22 in opposite directions may permit the ground engaging blade 16 to rotate or tilt relative to the machine 10. In other words, operating the pitch hydraulic cylinders 22 in this manner will permit the rotation of the ground engaging blade 16 generally about an attachment point of the ground engaging blade to the machine 10 so that opposite corners 19 of the bottom edge of the blade may be disposed at different heights relative to the ground. The machine of FIG. 2 depicts an alternate manner of affecting the rotation of ground engaging blade 16 by utilizing a tilt hydraulic cylinder 23. Each of the hydraulic cylinders may be electrically controlled and receive signals from a controller 30. Controller 30 generates a signal that may be translated into a direction and magnitude of movement of the appropriate hydraulic cylinders as will be understood by those skilled in the art.

[0018] Machine 10 includes cab 28 from which an operator may provide input to control machine 10. Cab 28 includes one or more controls with which the operator may issue commands. FIG. 1 shows a joystick 27 from which an operator may control one or more machine implements, such as ground engaging blade 16. Joystick 27 may be configured to automatically return to a “neutral” position if the operator is not moving joystick 27. The operator may move joystick 27 to either side to control the tilt or rotation of ground engaging blade 16 relative to machine 10. Joystick 27 may operate as part of a control system of machine 10 wherein the operator’s movement of joystick 27 (including the magnitude of the movement of joystick 27) is translated into a signal and sent to a controller 30. Movement of joystick 27 generates a signal to controller 30 indicative of the magnitude and direction of the operator’s movement of the joystick. As described in more detail below, the controller 30 may process the signal and potentially adjust the signal prior to issuing or generating a command signal to the tilt hydraulic cylinder 23 to adjust the cross slope or angular orientation of ground engaging blade 16.

[0019] Machine 10 may be equipped with a plurality of sensors that provide data indicative (directly or indirectly) of the performance or conditions of various aspects of the machine. A first sensor 33 such as a 3-axis accelerometer may be provided on the ground engaging blade 16 of machine 10. The first sensor 33 may be used to provide an acceleration

signal indicative of the measured acceleration of the ground engaging blade 16 relative to a gravity reference. As such, the cross slope angular position is a measurement of the ground engaging blade relative to a gravity reference. Changes in blade roll or cross slope may be determined and controlled through the use of the measured acceleration of the ground engaging blade 16.

[0020] A second sensor 34 such as a roll rate sensor (e.g., a gyroscope) may also be provided on the ground engaging blade 16 of machine 10. The second sensor 34 may be used to provide an additional signal such as a roll rate signal indicative of a measured roll rate of the ground engaging blade 16. The measured roll rate is the rate of change of the ground engaging blade 16 as it rotates about the axis of the machine 10. In other words, as the tilt hydraulic cylinder 23 causes the ground engaging blade 16 to rotate about an attachment point, the measured roll rate will be indicative of the velocity or rate of change of the position of the blade.

[0021] As described in more detail below, controller 30 may utilize the acceleration signal from first sensor 33 to determine changes in the cross slope of ground engaging blade 16. Controller 30 may perform various functions such as integrating, filtering and scaling the acceleration signal so as to provide a signal indicative of the angular position or cross slope of the ground engaging blade 16. The cross slope angular position may then be compared to a desired cross slope to determine whether and how the cross slope angular position of the ground engaging blade 16 should be adjusted.

[0022] Controller may also utilize the measured roll rate from second sensor 34 as further input to control the cross slope of ground engaging blade 16. Controller 30 may also perform various functions such as integrating, filtering and scaling the roll rate signal to provide a signal indicative of the angular position or cross slope of the ground engaging blade 16.

[0023] The signal generated from the first sensor 33 may be combined with the signal from the second sensor 34 to provide a more responsive and accurate measurement of the cross slope angular position of ground engaging blade 16. An accelerometer such as first sensor 33 may be used to provide the angular position of the ground engaging blade 16 but the determination of such position may be relatively slow, in part due to various functions and calculations that must be performed. A roll rate sensor such as second sensor 34 may be used to provide the angular position of the ground engaging blade 16 more quickly than an accelerometer but the determination of such position is generally less accurate over time. Accordingly, the signals from the first sensor 33 and the second sensor 34 may be combined, if desired, to provide a combined representation of the cross slope angular position of the ground engaging blade 16. Such combined representation includes the benefits of both the first sensor 33 and the second sensor 34. More specifically, the first sensor 33 generally provides greater accuracy over time and the second sensor 34 generally provides a more rapid response.

[0024] A control system may be provided to control the operation of the machine 10 including the cross slope control aspects of the system. The control system may include an electronic control module such as controller 30. The controller 30 may receive operator input command signals and control the operation of the hydraulic systems that operate the various hydraulic cylinders. The controller 30 may be mounted at any convenient location on machine 10. The control system may include one or more input devices such as

joystick 27 to control the machine 10 and one or more sensors, including first sensor 33 and second sensor 34, to provide data and other input signals representative of various operating parameters of the machine 10.

[0025] The controller 30 may be an electronic controller that operates in a logical fashion to perform operations, execute control algorithms, store and retrieve data and other desired operations. The controller 30 may include or access memory, secondary storage devices, processors, and any other components for running an application. The memory and secondary storage devices may be in the form of read-only memory (ROM) or random access memory (RAM) or integrated circuitry that is accessible by the controller. Various other circuits may be associated with the controller such as power supply circuitry, signal conditioning circuitry, driver circuitry, and other types of circuitry.

[0026] The controller 30 may be a single controller or may include more than one controller disposed to control various functions and/or features of the machine 10. The term “controller” is meant to be used in its broadest sense to include one or more controllers and/or microprocessors that may be associated with the machine 10 and that may cooperate in controlling various functions and operations of the machine. The functionality of the controller 30 may be implemented in hardware and/or software without regard to the functionality employed. The controller 30 may rely on one or more data maps relating to the operating conditions of the machine 10 that may be stored in the memory of controller. Each of these maps may include a collection of data in the form of tables, graphs, and/or equations. The controller 30 may use the data maps to maximize the efficiency of the machine 10.

[0027] Referring to FIG. 3, machine 10 may be equipped with a user switch (not shown) to activate the cross slope control aspects of the control system at stage 41. If the user switch is activated, the cross slope control system will operate in accordance with the flowchart of FIG. 3. If user switch is not activated or the cross slope control functionality is not operating properly, machine 10 will operate in accordance with the operator's commands regardless of the operating conditions encountered by the machine.

[0028] The operator provides a desired or target cross slope of ground engaging blade 16 at stage 42. This may be accomplished by entering the target cross slope through an input device such as a dial. The controller then stores a target cross slope signal indicative of the target cross slope. In an alternative embodiment, an operator may set the target cross slope by moving the ground engaging blade 16 to a desired orientation and engaging an input device such as by pressing a button (not shown). At stage 43, the controller 30 receives a measured cross slope signal from the first sensor 33 on the ground engaging blade 16 and a roll rate signal from the second sensor 34 on the ground engaging blade. The controller 30 determines a cross slope angular position based upon the measured cross slope signal and the roll rate signal. As used herein, the term “cross slope angular position” refers to the cross slope as determined by one or more sensors.

[0029] The controller 30 then compares at decision stage 44 the cross slope angular position to the desired or target cross slope set by the operator. If the difference between the cross slope angular position and the desired cross slope is zero or less than a predetermined amount, the controller 30 will not generate a command signal and the blade will be maintained at its current angular orientation at stage 45.

[0030] If the cross slope angular position is different from the desired or target cross slope, the controller 30 will determine at decision stage 46 whether certain predetermined threshold conditions have been met to activate the cross slope control system. One threshold condition may be that the machine transmission (not shown) is in a certain state (e.g. not in neutral). Another example of a threshold condition may be that the machine ground speed is above or below a threshold amount or that the engine speed is within a predetermined range. Still another threshold condition may be that one or more other control systems are not active in controlling the implement. This type of condition may be desirable if the machine is equipped with multiple different implement control systems that are mutually exclusive and therefore cannot operate together. Another threshold condition may be based upon the receipt of predetermined steering commands. For example, the controller may turn off the cross slope control system during certain turning operations. Other threshold conditions may be set as desired.

[0031] It should be noted that the determination of whether the threshold conditions have been met may be based upon monitoring the operating characteristics of aspects of the machine 10 for a particular period. In addition, different time periods may apply to different threshold conditions. If one or more of the threshold conditions have not been met at decision stage 46, the controller 30 will not generate a command signal and the cross slope of ground engaging blade 16 will not change. In other words, even if the machine 10 is undergoing a change in cross slope, the blade will follow the machine 10 during such change.

[0032] If, on the other hand, the necessary threshold conditions have been met at decision stage 46, the control determines at decision stage 47 whether the operator is issuing a tilt angle change command to change the cross slope of ground engaging blade 16. If the operator has issued a tilt angle change command at decision stage 47, the controller 30 will generate a command signal approximately or substantially equal to the operator tilt angle change command at stage 51. This command signal will then be transmitted at stage 52 by controller 30 to control the hydraulic cylinders necessary to implement the operator command. In other words, if the operator issues a tilt angle change command, the controller 30 will override the portion of the cross slope control system that would otherwise generate a command signal based upon the difference between the cross slope angular position and the target cross slope. The controller 30 will utilize the operator tilt angle change command signal as the command signal that is transmitted to control movement of the ground engaging blade 16.

[0033] If the operator did not issue a tilt angle change command at decision stage 47, the controller 30 generates a command signal based upon the difference between the cross slope angular position and the desired or target cross slope. At decision stage 54, the controller determines whether the ground engaging blade 16 is at its maximum travel position. In other words, the controller determines whether the command signals generated at stage 53 will cause the tilt hydraulic cylinder 23 to reach its maximum travel position and cause the ground engaging blade to reach its maximum cross slope position. In doing so, the controller 30 may compare the target cross slope to a maximum cross slope.

[0034] If the tilt hydraulic cylinder 23 has reached its maximum travel position, the controller at stage 55 will modify the command signal to generate a modified command signal to

limit the travel of the tilt hydraulic cylinder 23 and prevent movement of the ground engaging blade 16 past its predetermined maximum displacement. As such, the ground engaging blade will be maintained within its operating parameters and not exceed its maximum travel position. This modified command signal is then transmitted at stage 52 to control the tilt hydraulic cylinder 23. If the ground engaging blade 16 is not at its maximum travel position at decision stage 54, the controller does not change the generated command signal at stage 56, and the command signal is transmitted at stage 52 to control movement of the ground engaging blade 16 and maintain the ground engaging blade at the target cross slope. As such, the command signal is at least in part based upon a difference between the target cross slope and the cross slope angular position.

[0035] It can be seen from FIG. 3 that once an operator is no longer issuing an operator command (i.e., upon termination of the operator command signal) at decision stage 47, the controller 30 will follow stage 53 and attempt to return the ground engaging blade to the target cross slope. The cross slope control system will continue to operate until the operator suspends or disables the system such as by the user switch (not shown) or any of the threshold conditions are no longer met. In addition, it should be noted, that the operator may change the desired cross slope by returning to stage 42 at any time by inputting a new desired or target cross slope.

[0036] FIGS. 4-7 depict graphs of examples of the cross slope of a machine 10 and its ground engaging blade 16 as a function of time for a simulated movement of the machine 10. In FIG. 4, the change in machine roll angle is denoted by a line 61 as a function of time for the simulated movement of the machine 10. For this simulated movement, the target cross slope of the ground engaging blade 16 has been set to 0 degrees and the machine is initially operating at a 0 degrees cross slope. At time 0.0, the machine begins a constant change of roll angle for approximately 1.0 seconds and then maintains a new cross slope of 5 degrees. If the cross slope control system disclosed herein is not engaged or the threshold conditions not met, the ground engaging blade 16 would rotate with machine 10 so that it would have a cross slope of 5 degrees. If the system were to work instantaneously without any error, the ground engaging blade 16 would be maintained at 0 degrees even as the machine engages the slope.

[0037] As described above, if desired, the cross slope control system may utilize only the acceleration signal from the first sensor 33 to adjust the cross slope of the ground engaging blade 16. In FIG. 5, the cross slope angular position of ground engaging blade 16 is denoted at line 62 as a function of time for the same simulated movement of the machine 10 as FIG. 4 and with the control system receiving only the acceleration signal from first sensor 33. It can be seen that when utilizing only the first sensor 33, the ground engaging blade 16 will initially follow the machine 10 and the cross slope control system will not cause a significant deviation between the angular orientation of the ground engaging blade and the machine until after approximately 0.4 seconds. The cross slope control system will then adjust the angular orientation of the ground engaging blade so that the difference between the cross slope angular position and the target cross slope is decreased until the ground engaging blade 16 is rotated past the target cross slope as depicted at approximately 1.3 seconds. The system then corrects itself and the cross slope angular position moves closer to the target cross slope until they are identical. Thus, it can be seen, that the cross slope

control system will change the angular orientation of the ground engaging blade 16 in a relatively slow manner but such change will result in the cross slope angular position closely matching the desired cross slope over some period of time.

[0038] As also described above, if desired, the cross slope control system may also utilize the roll rate signal from the second sensor 34 to adjust the cross slope of the ground engaging blade 16. In FIG. 6, the cross slope angular position of ground engaging blade 16 is denoted at line 63 as a function of time for the same simulated movement of the machine 10 as FIG. 4 and with the control system receiving only the roll rate signal from second sensor 33. It can be seen that the cross slope control system quickly adjusts the cross slope so that the cross slope angular position of ground engaging blade 16 relatively closely matches the target cross slope. However, by using only the roll rate signal from second sensor 34, the cross slope control system is unable to determine the actual cross slope and adjust the ground engaging blade 16 accordingly. As a result, the actual angular position of the ground engaging blade 16 continues to increase from time 0.0 to approximately 1.0 seconds and then maintains a generally constant cross slope thereafter. Thus, the correction generated by utilizing only the second sensor 34 is relatively fast but does not rotate the ground engaging blade 16 back to the target cross slope.

[0039] If desired, the control system may use signals from both the first sensor 33 and the second sensor 34 to adjust the cross slope of ground engaging blade 16. Such a cross slope control system may relatively quickly and accurately adjust the angular orientation of the ground engaging blade 16 as denoted by line 64 in FIG. 7. The cross slope control system may combine or use the two signals in a variety of manners to obtain the maximum performance of the system. In one example, the cross slope control system may use the roll rate signal from the second sensor 34 for some period of time to initially control the ground engaging blade 16 and then use the acceleration signal from the first sensor 33 or a combination of the signals from the first sensor 33 and the sensor 34 to maintain the overall accuracy of the roll rate correction. For example, referring to FIGS. 4-7, it may be seen that the control system utilizes the roll rate controlled blade angle of FIG. 6 for approximately 0.4 seconds. At that point, the accelerometer controlled blade angle starts to correct for the change in cross slope (FIG. 5). The control system may either use only the accelerometer based correction or a combination of the roll rate based correction and the accelerometer based correction to guide the control system and adjust the cross slope of the ground engaging blade.

INDUSTRIAL APPLICABILITY

[0040] The industrial applicability of the system described herein will be readily appreciated from the foregoing discussion. The foregoing discussion is applicable to machines 10 that utilize an implement such as a ground engaging blade 16 for which it is desirable to control its angular orientation or cross slope. In one aspect, a control system is provided for controlling automated movement of a ground engaging blade 16 of a machine 10. The ground engaging blade 16 is configured for rotational movement about an axis to define a cross slope of the ground engaging blade. A first sensor is located on the ground engaging blade and configured to provide a measured cross slope signal indicative of a cross slope of the ground engaging blade. A second sensor is disposed on the ground engaging blade configured to provide a roll rate signal

indicative of a roll rate of the ground engaging blade. A controller 30 is configured to store a target cross slope signal indicative of a target cross slope of the ground engaging blade 16, determine a cross slope angular position based upon the measured cross slope signal and the roll rate signal, and compare the target cross slope to the cross slope angular position. The controller further generates a command signal at least in part based upon a difference between the target cross slope and the cross slope angular position to control movement of the ground engaging blade 16, maintain the ground engaging blade at the target cross slope, and transmit the command signal to control movement of the ground engaging blade.

[0041] In another aspect, a controller implemented method of adjusting a ground engaging blade 16 of a machine 10 is provided. The ground engaging blade 16 has a first sensor configured to provide a measured cross slope signal indicative of a cross slope of the ground engaging blade and second sensor configured to provide a roll rate signal indicative of a roll rate of the ground engaging blade. The method includes storing within a controller 30 a target cross slope signal indicative of a target cross slope of the ground engaging blade 16, determining a cross slope angular position based upon the measured cross slope signal and the roll rate signal, and comparing the target cross slope to the cross slope angular position. A command signal is generated within the controller at least in part based upon a difference between the target cross slope and the cross slope angular position to control movement of the ground engaging blade and maintain the ground engaging blade at the target cross slope. The command signal is transmitted from the controller to control movement of the ground engaging blade.

[0042] It will be appreciated that the foregoing description provides examples of the disclosed system and technique. However, it is contemplated that other implementations of the disclosure may differ in detail from the foregoing examples. In this regard, the disclosed system may employ roll rate and acceleration sensors that are already disposed on the blade for use in other control functions. That is, other roll rate and/or acceleration sensors may be employed to determine the cross slope of the ground engaging blade which may then be used to determine the difference between the target cross slope and the cross slope. All references to the disclosure or examples thereof are intended to reference the particular example being discussed at that point and are not intended to imply any limitation as to the scope of the disclosure more generally. All language of distinction and disparagement with respect to certain features is intended to indicate a lack of preference for those features, but not to exclude such from the scope of the disclosure entirely unless otherwise indicated.

[0043] Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

[0044] Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements

in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein or otherwise clearly contradicted by context.

What is claimed is:

1. A control system for automated movement of a ground engaging blade of a machine, the ground engaging blade being configured for rotational movement about an axis to define a cross slope of the ground engaging blade, comprising:

a first sensor disposed on the ground engaging blade configured to provide a measured cross slope signal indicative of a measured cross slope of the ground engaging blade;

a second sensor disposed on the ground engaging blade configured to provide a roll rate signal indicative of a roll rate of the ground engaging blade; and

a controller configured to:

store a target cross slope signal indicative of a target cross slope of the ground engaging blade;

determine the cross slope angular position based upon the measured cross slope signal and the roll rate signal;

compare the target cross slope to the cross slope angular position;

generate a command signal at least in part based upon a difference between the target cross slope and the cross slope angular position; and

transmit the command signal to maintain the ground engaging blade at the target cross slope.

2. The control system of claim 1, wherein the controller is further configured to receive an operator command signal, override the command signal with the operator command signal and transmit the operator command signal to control movement of the ground engaging blade.

3. The control system of claim 2, wherein the controller is further configured to return the ground engaging blade to the target cross slope upon termination of the operator command signal.

4. The control system of claim 1, wherein the cross slope angular position is a measurement of the ground engaging blade relative to a gravity reference.

5. The control system of claim 1, wherein the controller initially generates the command signal primarily based upon the roll rate signal.

6. The control system of claim 5, wherein the controller subsequently generates the command signal primarily based upon the measured cross slope signal.

7. The control system of claim 5, wherein the first sensor is an accelerometer.

8. The control system of claim 6, wherein the second sensor is a gyroscope.

9. The control system of claim 1, wherein the controller is further configured to compare the target cross slope to a maximum cross slope, and generate a modified command signal to prevent movement of the ground engaging blade past a predetermined maximum displacement.

10. The control system of claim 1, wherein the first sensor is an accelerometer.

11. The control system of claim 1, wherein the command signal moves the ground engaging blade when an operator has not commanded a specific movement of the ground engaging blade.

12. A controller implemented method of adjusting a ground engaging blade of a machine, the ground engaging blade having a first sensor configured to provide a measured cross

slope signal indicative of a measured cross slope of the ground engaging blade, and a second sensor disposed on the ground engaging blade configured to provide a roll rate signal indicative of a roll rate of the ground engaging blade, comprising:

storing within a controller a target cross slope signal indicative of a target cross slope of the ground engaging blade;

determining a cross slope angular position based upon the measured cross slope signal and the roll rate signal;

comparing the target cross slope to the cross slope angular position;

generating a command signal within the controller at least in part based upon a difference between the target cross slope and the cross slope angular position; and

transmitting the command signal from the controller to a control system to maintain the ground engaging blade at the target cross slope.

13. The controller implemented method of claim **12**, further including receiving an operator command signal within the controller, overriding the command signal with the operator command signal and transmitting the operator command signal from the controller to control movement of the ground engaging blade.

14. The controller implemented method of claim **13**, further including returning the ground engaging blade to the target cross slope upon termination of the operator command signal.

15. The controller implemented method of claim **12**, further including measuring cross slope as a measurement of the ground engaging blade relative to a gravity reference.

16. The controller implemented method of claim **12**, further including initially generating the command signal pri-

marily based upon the roll rate signal and subsequently generating the command signal primarily based upon the measured cross slope signal.

17. The controller implemented method of claim **12**, further including comparing the target cross slope to a maximum displacement cross slope, and generating within the controller a modified command signal to prevent movement of the ground engaging blade past a predetermined maximum displacement.

18. A machine comprising:

a ground engaging blade;

a first sensor on the ground engaging blade configured to provide a measured cross slope signal indicative of a measured cross slope of the ground engaging blade;

a second sensor disposed on the ground engaging blade configured to provide a roll rate signal indicative of a roll rate of the ground engaging blade; and

a controller configured to:

store a target cross slope signal indicative of a target cross slope of the ground engaging blade;

determine a cross slope angular position based upon the measured cross slope signal and the roll rate signal;

compare the target cross slope to the cross slope angular position;

generate a command signal at least in part based upon a difference between the target cross slope and the cross slope angular position; and

transmit the command signal to maintain the ground engaging blade at the target cross slope.

19. The machine of claim **18**, wherein the controller initially generates the command signal primarily based upon the roll rate signal.

20. The machine of claim **19**, wherein the first sensor is an accelerometer and the second sensor is a gyroscope.

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