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(54) **METHOD FOR CONTROLLING AN ELECTRIC DRIVE MACHINE**

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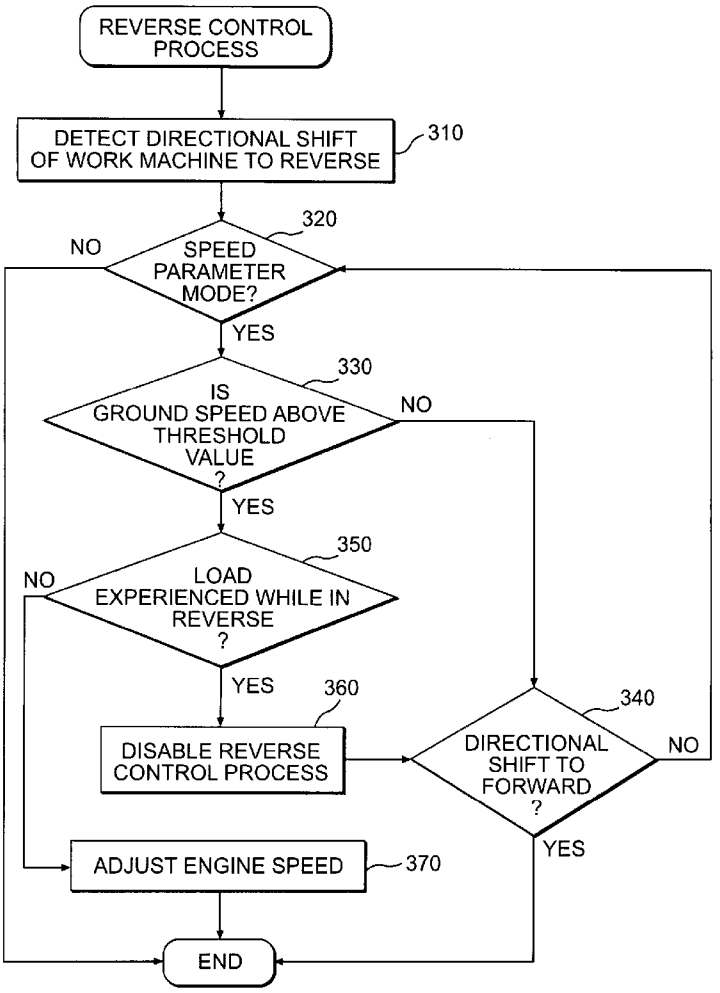
(57) **ABSTRACT**

A method is provided for controlling an electric drive work machine including an engine and an electric motor that provides power to enable the work machine to travel across a surface terrain at certain ground speeds. In one embodiment, the method may include detecting a reverse directional shift of the work machine causing the work machine to travel in a reverse direction. Further, the method may include performing an engine speed reduction process that reduces a current speed of the engine based on the detected reverse directional shift without reducing a ground speed of the work machine while traveling in the reverse direction.



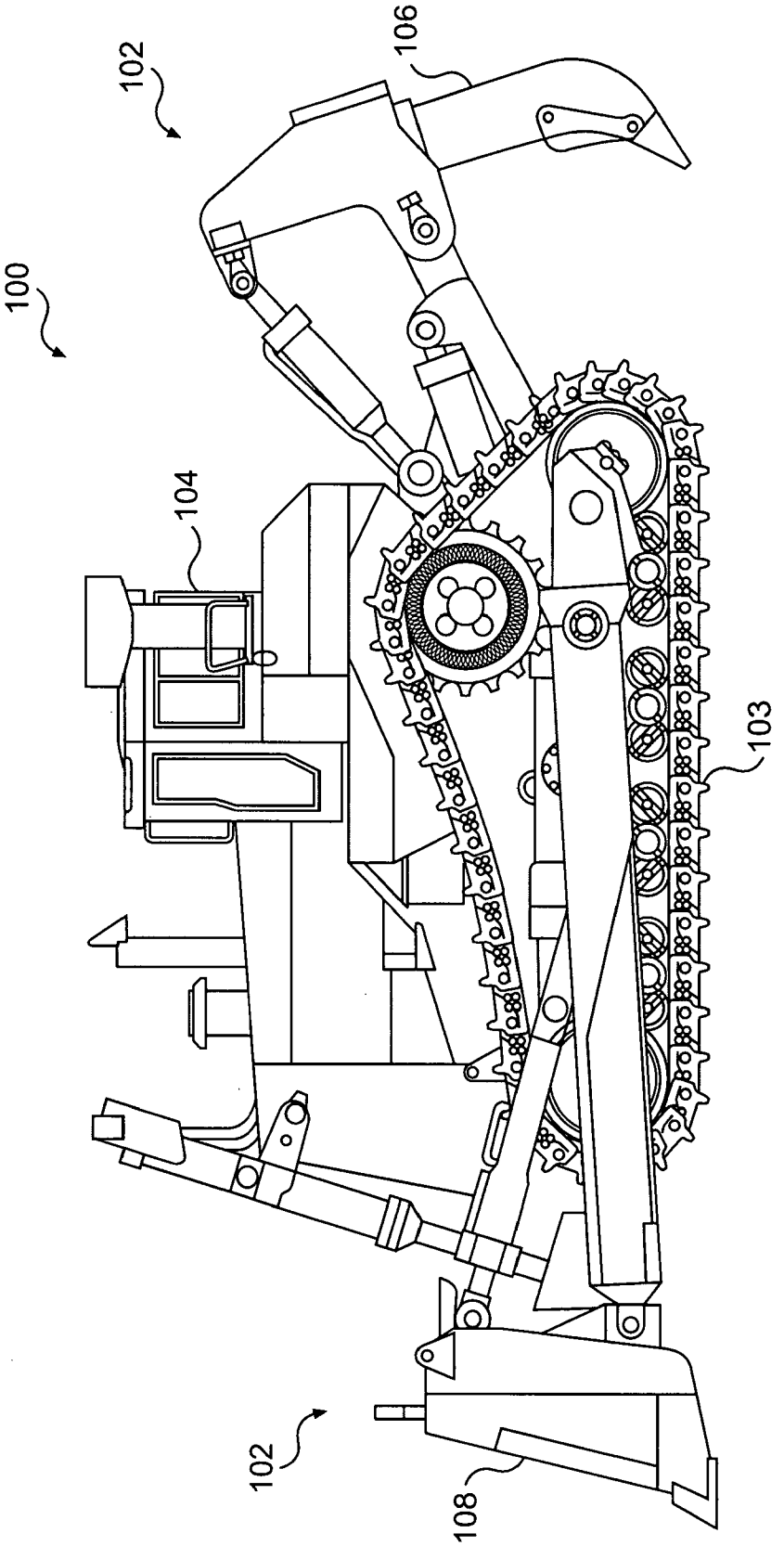


FIG. 1A

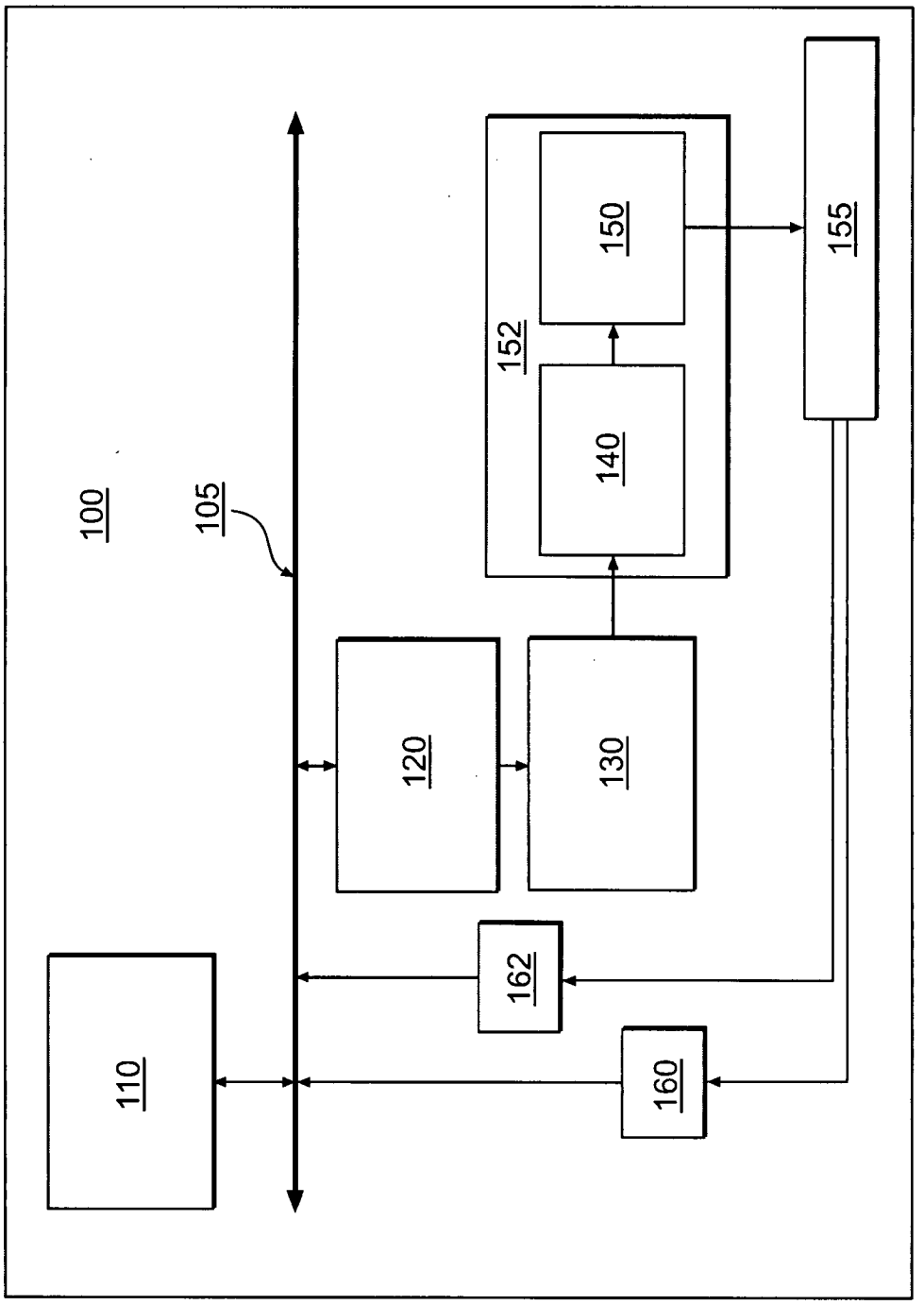


FIG. 1B

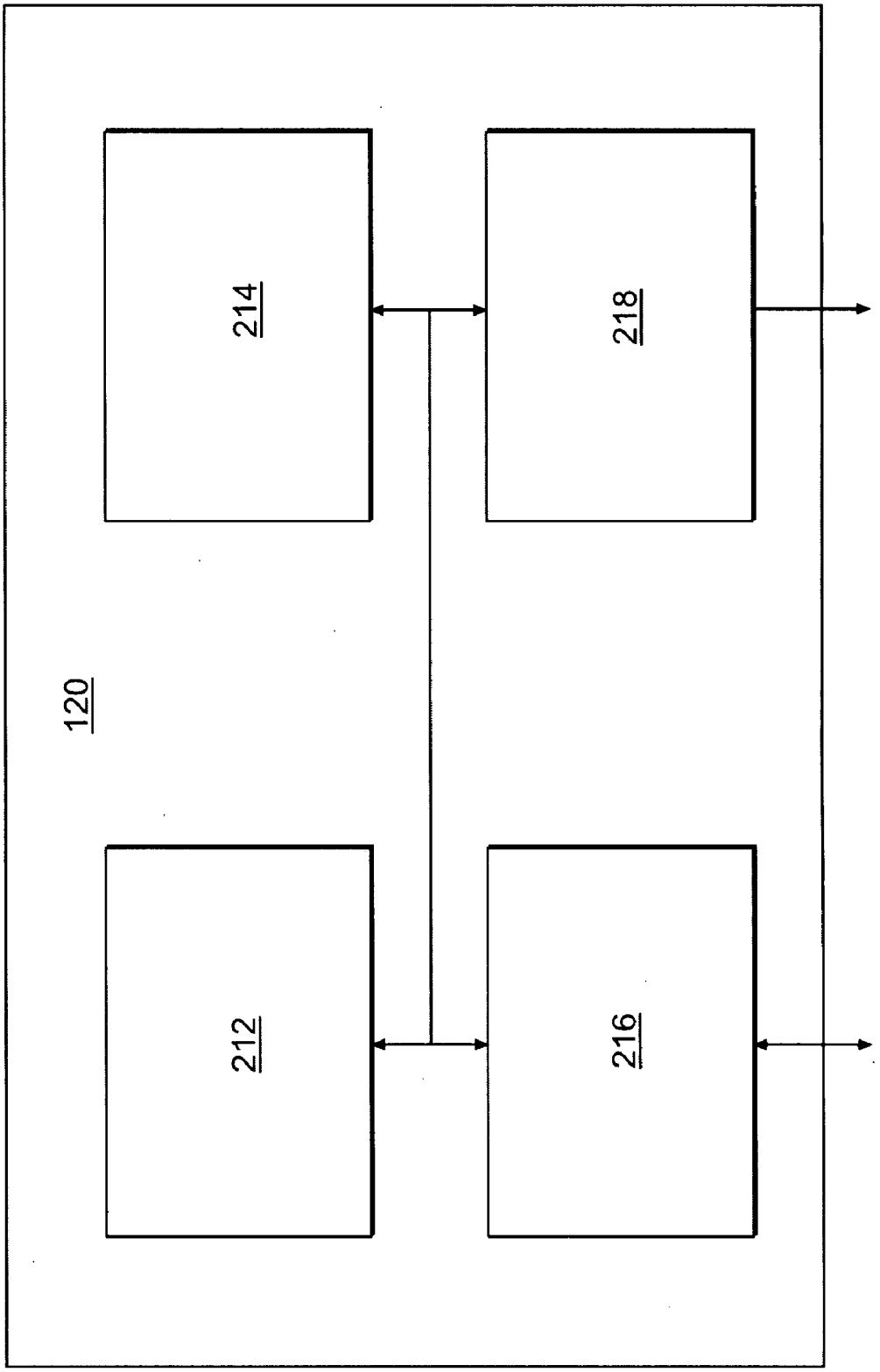


FIG. 2

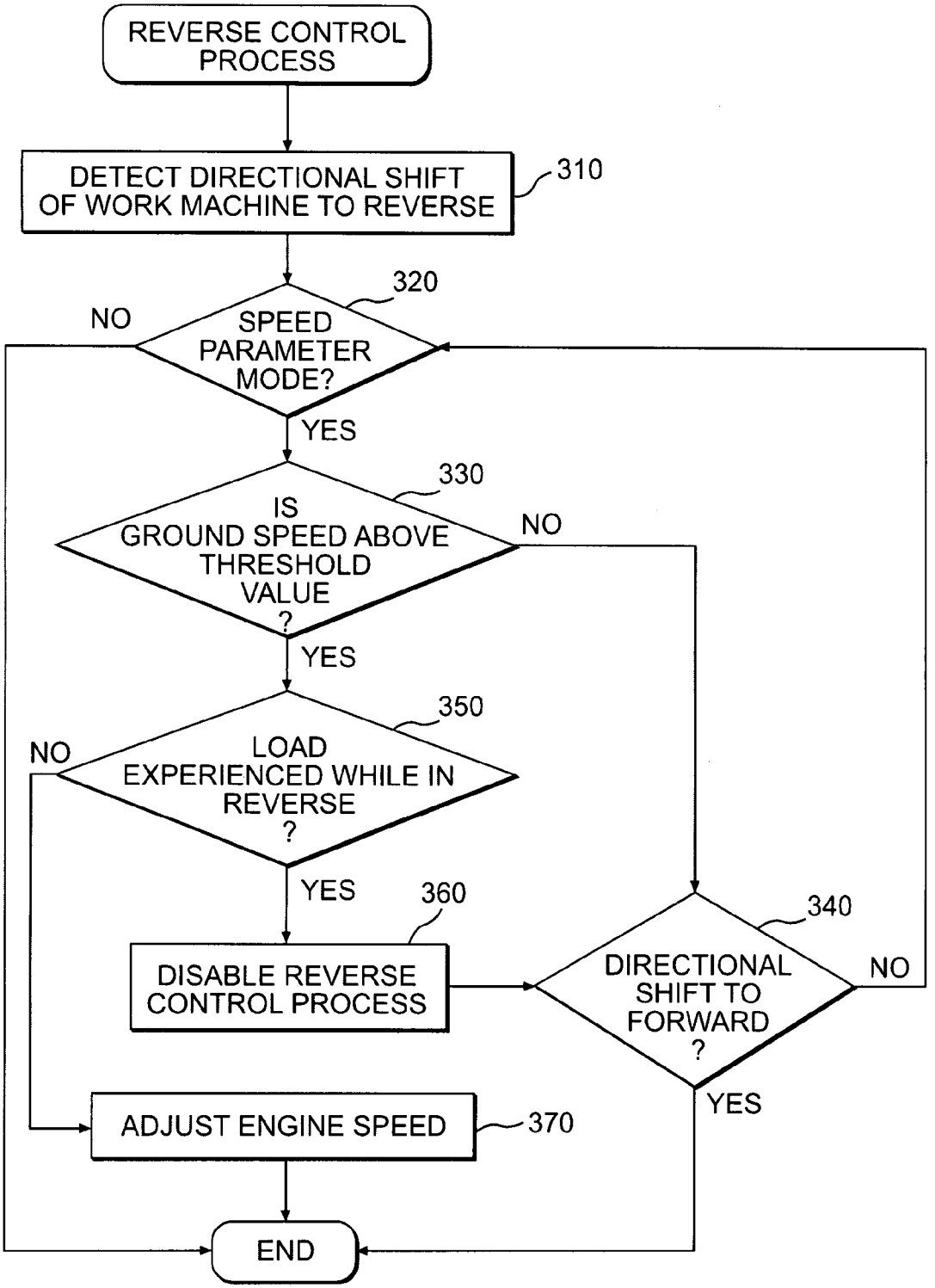

REVERSE CONTROL PROCESS
DETECT DIRECTIONAL SHIFT OF WORK MACHINE TO REVERSE
310
320
SPEED PARAMETER MODE?
NO
YES
330
IS GROUND SPEED ABOVE THRESHOLD VALUE ?
NO
YES
350
LOAD EXPERIENCED WHILE IN REVERSE ?
NO
YES
360
DISABLE REVERSE CONTROL PROCESS
340
DIRECTIONAL SHIFT TO FORWARD ?
NO
YES
ADJUST ENGINE SPEED
370
END

FIG. 3

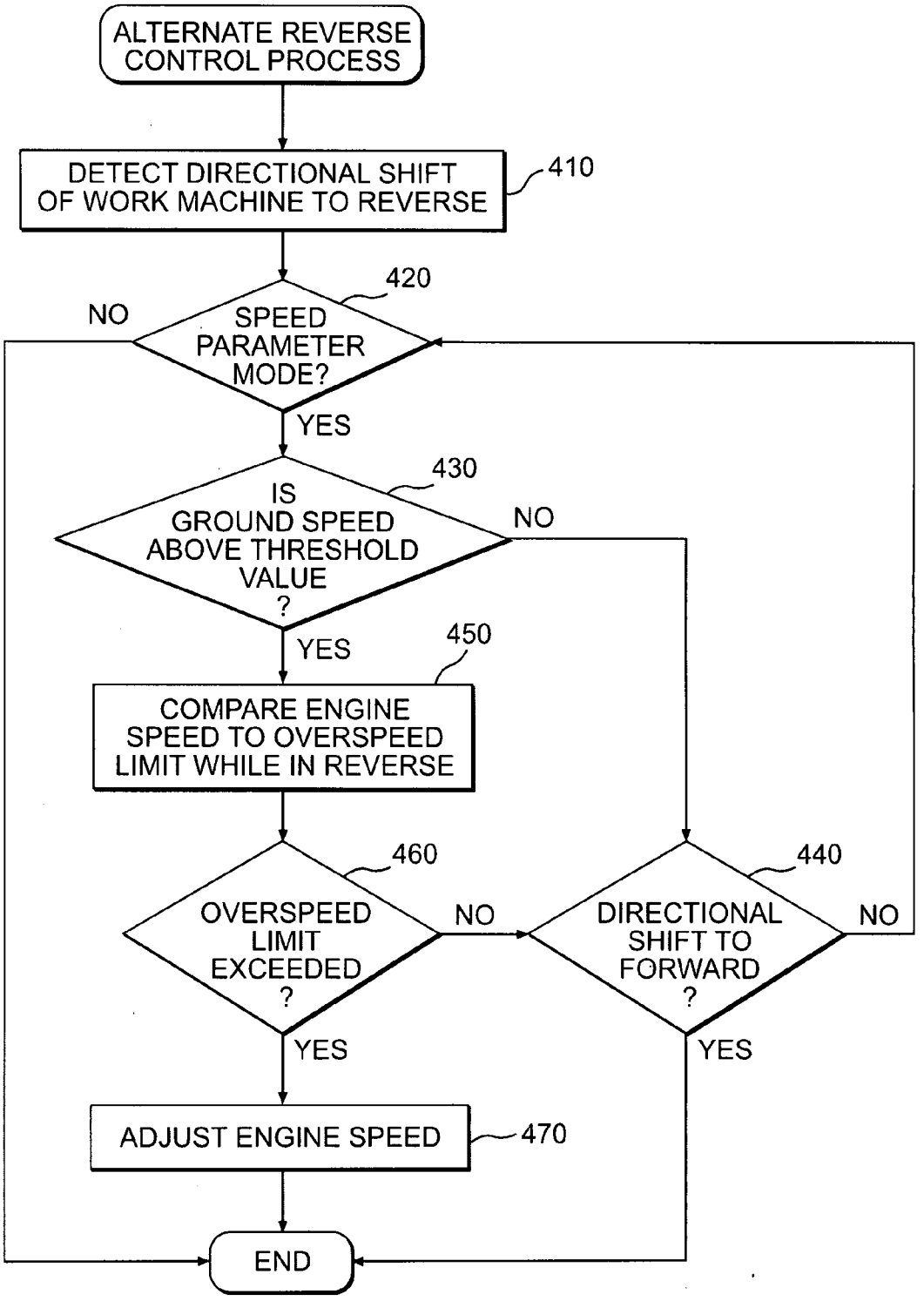

ALTERNATE REVERSE CONTROL PROCESS
DETECT DIRECTIONAL SHIFT OF WORK MACHINE TO REVERSE
410
420
NO
SPEED PARAMETER MODE?
YES
430
IS GROUND SPEED ABOVE THRESHOLD VALUE ?
NO
YES
450
COMPARE ENGINE SPEED TO OVERSPEED LIMIT WHILE IN REVERSE
460
OVERSPEED LIMIT EXCEEDED ?
NO
440
DIRECTIONAL SHIFT TO FORWARD ?
NO
YES
YES
ADJUST ENGINE SPEED
470
END

FIG. 4

METHOD FOR CONTROLLING AN ELECTRIC DRIVE MACHINE

TECHNICAL FIELD

[0001] This invention relates generally to electric drive machines and more particularly, to systems and methods for controlling the engine speed of an electric drive work machine.

BACKGROUND

[0002] The increase in fossil fuel consumption coupled with the diminishing supply of these resources have given rise to the implementation of electric drive machines. These machines may be designed to provide combinations of electric and/or internal combustion power to the machines' drive train to reduce fuel consumption. In some configurations, an engine powers a generator, which provides electric power to a battery system and an electric motor. Typically, the electric motor is configured to drive the wheels or travel mechanisms of the work machine (e.g., sprockets on a track type tractor, etc.). Other types of electric drive machines allow both an engine and electric motor to provide power to the travel mechanisms of the work machine.

[0003] The evolution of electric drive machines have also given rise to new types of systems for controlling the power produced by the electric motor and/or engine. Typically, conventional control systems for electric drive machines use various machine operating conditions and parameters to adjust the operations of the machine's engine and/or electric motor in an attempt to increase the performance efficiency of the work machine.

[0004] Although conventional systems may control an engine in an electric drive machine, such control is based on anticipated changes to the work loads experienced by the vehicle. Accordingly, these systems may require extensive processing capabilities to determine the appropriate adjustments to be made to the operation of the engine to offset the loads experienced by the machine's motor. Such processing is sometimes not feasible in working environments where a work machine performs repeated motions that require many directional shifts and speed fluctuations. To reduce losses experienced by a work machine in such conditions, some control systems have been developed that take into account machine speed or directional fluctuations. One such system is described in U.S. Pat. No. 5,725,064 ("the '064 patent"), which uses a control system to cut off the fuel supply of an electric drive machine's engine when the machine is in reverse, when an auxiliary component is running during idle conditions, or when the motor is exclusively used to drive the machine. The control system in the '064 patent decompresses the engine following its shut down to reduce engine pumping losses. This reduces drag on the motor that may result from the shut down of the engine.

[0005] Although the system described in the '064 patent uses a control system to increase the efficiency of an electric drive machine, it does so in a manner requiring the engine to be shut down. Thus, the vehicle relies on the electric motor for mobility while in reverse. Further, the '064 patent, as well as other conventional electric drive control systems, do not consider overspeed limit conditions during directional shifts. Accordingly, there is a need for an electric drive control system that controls an engine based on directional shifts without complex processing or drastic mechanical changes in order to increase fuel efficiency and overspeed limit capabilities during certain directional shift conditions.

[0006] Methods, systems, and articles of manufacture consistent with the disclosed embodiments are directed to solving one or more of the problems set forth above.

SUMMARY

[0007] A method is provided for controlling an electric drive work machine including an engine and an electric motor that provides power to enable the work machine to travel across a surface terrain at certain ground speeds. In one embodiment, the method may include detecting a reverse directional shift of the work machine causing the work machine to travel in a reverse direction. Further, the method may include performing an engine speed reduction process that reduces a current speed of the engine based on the detected reverse directional shift without reducing a ground speed of the work machine while traveling in the reverse direction.

[0008] In another embodiment, a system is provided for controlling an electric drive work machine. The system may include an engine, an electric motor that provides power to a travel mechanism that allows the work machine to travel across a terrain surface at certain ground speeds and an engine control system. The engine control system may be configured to determine when the work machine experiences a reverse directional shift causing the work machine to operate in a reverse direction. Based on the detected directional shift the engine control system may send an engine control signal to the engine that reduces the speed of the engine from a current engine speed to an adjusted engine speed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1**A illustrates a block diagram of an exemplary work machine consistent with certain disclosed embodiments;

[0010] FIG. **1**B illustrates a block diagram of an exemplary system that may be configured to perform certain functions consistent with disclosed embodiments;

[0011] FIG. **2** illustrates a block diagram of an exemplary control system consistent with certain disclosed embodiments;

[0012] FIG. **3** illustrates a flowchart of an exemplary reverse control process consistent with certain disclosed embodiments; and

[0013] FIG. **4** illustrates a flowchart of another exemplary reverse control process consistent with certain disclosed embodiments.

DETAILED DESCRIPTION

[0014] Reference will now be made in detail to certain embodiments, which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[0015] FIG. **1**A illustrates an exemplary work machine **100**, shown as a track type work machine, equipped with

work implements **102** and capable of performing various production operations, such as ripping, grading, and moving material. Work machine **100** may include an operator's cab **104** wherein an operator is positioned to operate work machine **100**. Although work implements **102** are shown as being a ripper **106** and dozing blade **108**, it should be understood that any type of work implements (e.g., dozer blades, buckets, forks, etc.) or none at all may be implemented and used by work machine **100**. Work machine **100** may also include travel mechanisms, such as tracks **103**, that engage the ground and is capable of operating in forward and reverse on level or sloped terrains.

[**0016**] Further, although work machine **100** is shown as a track type tractor machine, machine **100** may be any type mobile machine that performs at least one operation associated with a particular industry, such as mining, construction, farming, etc. and operates between or within work environments (e.g., construction site, mine site, power plant, etc.). Work machine **100** may also be a mobile machine for use in non-industrial settings (e.g., machines for personal use). For example, work machine **100** may represent a commercial machine, such as a truck, a crane, earth moving vehicle, a mining vehicle, a backhoe, material handling equipment, farming equipment, and other types of machines that operate in a commercial or industrial environment. In one embodiment, work machine **100** is an electric drive work machine that includes an electric motor that provides at least some power to a drive train of work machine **100**.

[**0017**] Also, in accordance with certain embodiments, work machine **100** may be a machine that performs tasks that require repeated transitions from a forward and reverse direction while performing these tasks. For example, work machine **100** is depicted as a track type machine that may be used by an operator to manipulate material or terrain using work implements **102** by continuously moving machine **100** forward and backward during the course of the manipulations.

[**0018**] FIG. **1**B illustrates a block diagram of certain components of work machine **100** that may be configured to perform certain functions consistent with certain embodiments. As shown, work machine **100** may include at least an on-board data link **105**, a work machine control system **110**, an engine control system **120**, an engine **130**, a generator system **140**, an electric motor **150**, travel mechanism **155**, and one or more sensors **160** and **162**.

[**0019**] On-board data link **105** represents one or more proprietary and/or non-proprietary data links that interconnect modules included in work machine **100**. In one embodiment, data link **105** may represent Society of Automotive Engineers (SAE) J1939, Controller Area Network (CAN), etc. standard data links.

[**0020**] Control system **110** represents one or more systems, devices, and/or mechanisms configured to perform certain control functions for work machine **100** and/or components of work machine **100**. Control system **110** may be implemented by one or more hardware, software, and or firmware components. In certain embodiments, control system **110** may be an Engine Control Unit (ECU) embedded in work machine **100**, although other forms of control modules may be implemented. Control system **110** may receive sensor signals from one or more sensors within work machine **100** and produce commands for controlling one or more other elements of work machine **100**, including other control systems.

[**0021**] Engine control system **120** represents one or more systems, devices, and/or mechanisms configured to perform certain control functions for work machine **100** and/or components of work machine **100**, such as engine **130**. Control system **120** may be implemented by one or more hardware, software, and or firmware components. In certain embodiments, control system **120** may be an ECU embedded in work machine **100**, although other forms of control modules may be implemented. Control system **120** may receive signals and commands from control system **110**. Based on these signals and commands, control system **120** may generate one or more signals for controlling the operations of engine **130**.

[**0022**] Engine **130** represents an engine that provides power for work machine **100** and its components. Engine **130** may be a diesel engine (although other types of engines are contemplated) that generates and transfers power to other components of work machine **100** through a power transfer mechanism, such as a shaft.

[**0023**] Electric motor **150** represents a motor that transfers the electric power received from generator **140** into power that drives one or more ground travel mechanisms **155**. Collectively, generator **140** and electric motor **150** may represent a drive train system **152** for work machine **100**, although additional components (not shown) may be included in this system.

[**0024**] Ground travel mechanism **155** may represent one or more types of mechanical components that allow work machine **100** to travel on the surface of a type of terrain (i.e., earth surface terrain, subterranean surfaces, underwater surfaces, etc.). Such components may include wheels, axles, tracks, sprockets associated with tracks, etc. As work machine **100** travels on a terrain surface, one or more sensors **160** may measure, collect, and send speed signals to control system **110** reflective of the speed of the machine. Sensor **160** may send speed signals to control system **110** in response to a request from system **110**, or sensor **160** may be configured to send the speed signals periodically or in response to a machine event, such as increase in speed, a deceleration event, etc. Further, work machine **100** may change directions while traveling. Sensor **162** may be a device that senses directional shifts of work machine **100** through various components, such as engine **130**, a transmission system (not shown), travel mechanism **155**, etc. Sensor **162** may be configured to send one or more directional shift signals to control system **110** directly or indirectly. Alternatively, or additionally, sensor **162** may send directional shift signals to engine control system **120** for subsequent processing.

[**0025**] Additionally, or alternatively, work machine **100** may sense directional shifts based on operator inputs associated with the direction of work machine **100**. For example, if the operator changes the direction of machine **100** through operator inputs (e.g., forward or reverse directional mechanisms in the cab of machine **100**), one or more signals indicative of this directional shift may be provided to control system **110** or a control system associated with drive train system **152**. Further, work machine **100** may include a sensor that monitors the position of components within

motor **150** that reflect the direction of work machine **100**. The motor sensor may send these signals to control system **110** or a control system associated with drive train system **152** for determining the direction of work machine **100**.

[**0026**] In another embodiment, sensor **162** may also include a sensor device that monitors and collects engine speed information from engine **130**. Sensor **162** may send this information in the form of an engine speed signal to control system **110** and/or engine control system **120** for processing consistent with certain disclosed embodiments. Further, work machine **100** may include sensors that measure the rotational speed of an axle used in travel mechanism **155** that is proportional to the ground speed of machine **100** or similar sensors capable of measuring actual ground speed of work machine **100** through other components of work machine **100**.

[**0027**] In certain embodiments, control system **110** sends one or more commands to one or more components of work machine **100** for controlling their operations. For example, control system **110** may send a command to control system **120** in response to signals sent or collected from sensors **160** and/or **162**.

[**0028**] Engine control system **120** may be configured to perform standard engine control unit functions for work machine **100**. Additionally, engine control system **120** may be configured to initiate and perform one or more engine control processes consistent with certain embodiments. FIG. **2** shows an exemplary engine control system **120** according to these embodiments. As shown, engine control system **120** may include a processing unit **212**, a memory device **214**, a sensor interface **216**, and a control signal interface **218**.

[**0029**] Processing unit **212** may represent one or more logic and/or processing components used by control system **120** to perform certain communications, control, and health test functionalities. For example, processor unit **212** may be configured for routing information among devices within and/or external to control system **120**. Further, processing unit **212** may be configured to execute executing instructions from a storage device, such as memory **214**. Although FIG. **2** illustrates a single processor unit, control system **120** may include a plurality of processor units, such as one or more general purpose processing units and/or special purpose processor units (e.g., ASICS). Processing unit **212** may also include, for example, one or more of the following: a co-processor, memory, registers, and other processing devices and systems as appropriate.

[**0030**] In certain embodiments, the functionality of processing unit **212** may be embodied within an integrated microprocessor or microcontroller. Such a microcontroller may, for example, include an integrated CPU, memory, and one or more peripherals. Depending on the implementation, engine control system **120** may include one or more microcontrollers in addition to or in place of processing unit **212** and memory **214**, such as the Microchip's PIC, the 8051, Intel's 80196, and Motorola's 68HCxx series microcontrollers.

[**0031**] Memory **214** may represent one or more systems and/or mechanisms capable of storing information. Memory **214** may be embodied with a variety of components and/or subsystems, including a RAM (random access memory), a ROM (read-only memory), magnetic and optical storage elements, organic storage elements, audio disks, and video disks. In certain embodiments, memory **214** may include one or more programmable, erasable and/or re-useable storage components, such as EPROM (erasable programmable read-only memory) and EEPROM (erasable programmable read-only memory). Memory **214** may also include constantly-powered nonvolatile memory operable to be erased and programmed in blocks, such as flash memory (i.e., flash RAM). Memory **214** may provide a primary memory for processor **212**, such as for storing program code. For example, memory **214** may include program code for communications, kernel and device drivers, configuration information, and other applications that might be embedded within control system **120**. Although a single memory is shown, any number of memory devices may be included in control system **120**, and each may be configured for performing distinct functions. In one embodiment, memory **214** may include program code that, when executed by processing unit **212**, performs one or more engine control processes consistent with certain embodiments.

[**0032**] Sensor interface **216** may be an optional device that is configured to receive one or more sensor signals from one or more respective sensor devices (e.g., sensors **160**, **162**) that are associated with one or more corresponding components of work machine **100**. In one embodiment, engine control system **120** extracts the signals received at sensor interface **216** and provides them to processing unit **212** and/or memory **214** for subsequent processing. Alternatively, engine control system **120** may receive sensor signals over a data link (e.g., data link **105**) and data link interface **218**.

[**0033**] Data link interface **218** may represent one or more interface devices that interconnect one or more data links (e.g., data link **105**) with engine control system **120**. Data link interface **218** may connect to proprietary and non-proprietary data links. In one embodiment, data link interface **218** may include virtual (i.e., software-based) ports that allow a single connection to act as if there were multiple connections.

[**0034**] Methods and system consistent with certain disclosed embodiments enable engine control system **120** to perform work machine control operations and processes. In one embodiment, work machine **100** may perform one or more processes that increase the performance efficiency of work machine **1100** through direct or indirect affects to one or more of the machine's components, such as engine **130**, motor **150**, etc. For example, work machine **100** may adjust operations of engine **130** and/or other components, while traveling in certain directions, such as reverse.

[**0035**] During operation, work machine **100** may perform work related duties (e.g., traveling, hauling, moving earth, etc.) at various ground speeds, engine speeds, directions, etc. while manipulating various types of loads. In some instances, work machine **100** may perform cyclical work operations. For example, work machine **100** may repeatedly change directions and engine speeds while moving or hauling some type of load, such as when a track type tractor machine moves forward pushing a load (e.g., earth), backs up while experiencing little or no external loads, and moves forward again to push the load. This cyclical process may be repeated all day, or in some instances, all day and night, depending on the type of work performed by work machine

100 and/or the type of work environment work machine 100 may be operating. In one embodiment, work machine 100 may be configured to perform one or more control processes that take into account the directional shift, load, and/or engine speed changes work machine 100 may experience while performing such work related duties.

[0036] FIG. 3 illustrates a flowchart of an exemplary reverse control process that may be performed by engine control system 120 and/or other elements of work machine 100. As mentioned above, work machine 100 may change directions many times while performing one or more tasks. Accordingly, in one embodiment, engine control system 120, control system 110, or other control systems (e.g., a control system associated with drive train system 152) may be configured to detect when work machine 100 experiences a directional shift to reverse (Step 310). To detect such a change, control system 110 may receive a directional shift signal from sensor 162 indicating that work machine 100 has shifted to a reverse direction or mode of operation causing a direction shift to a reverse direction. Sensor 162 may generate the directional shift signal based on information collected from travel mechanisms 155, such as the rotation of a sprocket changing direction, based on information collected from a transmission system (not shown), or based on user interface components that provides a signal reflecting that an operator has shifted the direction of work machine 100 to a reverse direction. The above examples are not intended to be limiting and other methods of detecting when work machine 100 has experienced a reverse directional shift may be implemented.

[0037] Once control system 110 receives the directional shift signal from sensor 162, it may generate and send a message to engine control system 120 over data link 105. The message may include information reflecting the directional shift. Alternatively, sensor 162 may send the directional shift signal to engine control system 120 directly (via sensor interface 216) or indirectly through data link 105 and data link interface 218. Once received, engine control system 120 may execute a reverse control program stored in memory 214. In one embodiment, the reverse control program may perform a process that determines whether engine control system 120 is configured in a speed parameter mode (Step 320). The speed parameter mode may be a mode of operation that allows engine control system 120 to make adjustments to the operations of engine 130 based on the speed of work machine 100 (e.g., mph) and/or the speed of engine 130 (e.g., RPM). If engine control system 120 is not configured in a speed parameter mode (Step 320; NO), the reverse control process continues at Step 370, described below. On the other hand, if engine control system 120 is configured in a speed parameter mode (Step 320; YES), system 120 may determine whether the ground speed of work machine 100 is above a predetermined threshold value while traveling in the reverse direction (Step 330).

[0038] In one embodiment, engine control system 120 may determine the ground speed of work machine through sensor, 160. For example, as work machine travels across a terrain surface, sensor 160 may collect ground speed information from travel mechanism 155 indicating the ground speed. Sensor 160 may send this information to control system 110 for forwarding to engine control system 120 in the form of a message delivered over data link 105. Alternatively, sensor 160 may send a speed signal to engine control system 120 through sensor interface 216 or indirectly through data link interface 218. Work machine 100 may implement different techniques and components for determining ground speed. For example, in one embodiment, engine control system 120 (or control system 110) may be configured to request the speed sensor data from sensor 160 when it detects a directional shift, as performed in Step 310. Alternatively, ground speed may be determined through sensors that provide signals associated with the rotational speed of the torque converter system output shaft connected to drive train system 152.

[0039] Once the ground speed of work machine 100 is determined, engine control system 120 may compare this speed to a predetermined ground speed threshold value that is programmed in memory 214. The ground speed threshold value may be a value determined by a user, a computer executed program, or a combination of user and computer executed processes. Further, the ground speed threshold value may be based on one or more specifications associated with one or more components of work machine 100.

[0040] In one embodiment, the operator of work machine 100, or another user, may select a maximum or desired reverse ground speed prior to, or while, performing some task with machine 100. The operator or user may use a user interface component within machine 100 for selecting the desired ground speed value. The interface component may be analog or digitally-based and provides a mechanism for the user or operator to select and change a maximum reverse ground speed value for work machine 100. Once the maximum ground speed value is selected, work machine 100 may execute a computer process to determine the ground speed threshold value based on the value selected by the operator or user. In one embodiment, work machine 100 may determine the ground speed threshold value based on a percentage of the maximum ground speed value selected by the operator or user. Thus, if the maximum ground speed is selected as 7 mph, work machine 100 may determine the ground speed threshold value as a percentage of the 7 mph value, such as 80% or 5.6 mph.

[0041] The above ground speed values are exemplary only and not, intended to be limiting. Work machine 100 may allow the maximum ground speed value and/or the percentage value used to determine the ground speed threshold value to be many different values. Further, disclosed embodiments may allow the ground speed threshold value to be determined based on other input values or signals. For instance, a user or operator may manually select the ground speed threshold value using an interface device within work machine 100. Further, the ground speed threshold value may be determined based on other types of values, such as engine speed values in RPM. Thus, a user or computer process may select a maximum engine speed using an interface device in work machine 100, and the ground speed threshold value may be determined based from the selected maximum engine speed value.

[0042] Returning to Step 330, if work machine 100 determines that the ground speed of work machine 100 does not exceed the threshold value (Step 330; NO), engine control system 120 may determine whether work machine 100 has experienced a directional shift to a forward direction (Step 340). Work machine 100 may employ various techniques and components for determining when a directional shift has

occurred, such as those describe above in connection with Step **310**. For example, signals indicative of operator input related to a manual change from a forward to reverse (or reverse to forward) direction may be provided to engine control system **120** or control system **110** to determine directional shifts. Alternatively, sensor signals from various components, such as motor **150** travel mechanism **155**, etc., may reflect directional shifts. Control systems **120** or **110** may receive these sensor signals to detect the change in directional movement of machine **100**.

[**0043**] If no forward directional shift is detected (Step **340**; NO), the reverse control process continues at Step **320**. If, however, a directional shift to a forward direction is detected (Step **340**; YES), the reverse control process ends.

[**0044**] Alternatively, in place of or in addition to detecting directional shifts, the reverse control process may be terminated in Step **340** based on a certain ground speed value or a range of ground speed values of work machine **100**. For example, as work machine **100** decelerates while traveling in reverse, a control system (e.g., system **110**, **120**, or a system associated with drive train system **152**) may determine whether the ground speed of machine **100** has reached a certain value or is within a certain range of values. Based on this determination, work machine **100** may terminate the reverse control process. For instance, should work machine **100** reduce its ground speed while traveling in reverse below a certain value or within a range of values (e.g., 0.25 or 0 mph, or between 0.25 and 0 mph), machine **100** may determine that the machine may be approaching a directional shift condition, and thus terminates the reverse control process in anticipation of a directional shift to a forward direction. Additional or other methods of detecting directional shifts or determining conditions for terminating the reverse control process may be implemented by work machine **100**.

[**0045**] Referring back to Step **330**, if engine control system **120** determines that the ground speed of work machine **100** has exceeded the threshold value (Step **330**; YES), system **120** may determine whether work machine **100** is experiencing a load while traveling in the reverse direction (Step **350**). An experienced load may be associated with changes in external or internal conditions due to operations of work machine **100**. For example, a load be experienced based on a change in gradient slope that work machine **100** may be traveling, such as a hill. Alternatively, or additionally, work machine **100** may experience a load by performing a certain task using one or more work elements **102** while traveling in a reverse direction, such as pushing, pulling, and carrying a load (e.g., earth, materials, etc.) using work elements **102**. This is distinguished from a condition where work machine **100** is backing up on a level terrain, or without performing some type of extraneous work, such as hauling, dragging, pulling, etc. Based on these conditions, certain components of work machine **100** may perform operations that result in machine **100** experiencing a change in load. For instance, work machine **100** may experience steering loads from steering pumps, drawbar loads, and any other type of load that may take place as a result in terrain changes, modifications in the type of operations work machine **100** performs while traveling in reverse, and/or operations of one or more components within machine **100**.

[**0046**] In certain embodiments, work machine **100** may detect a load using one or more sensors (not shown) that detect changes in slope of terrain, weight of work machine **100**, angles of work components, such as a work element **102**, and even increases in engine speed due to the work being performed. For instance, work machine **100** may be configured to detect when the speed of engine **130** drops or exceeds a predetermined value in RPM. Based on these detected changes in speed, work machine **100** may determine that machine **100** is experiencing a load. Alternatively, or additionally, work machine **100** may detect a load when the amount of fuel provided by the fuel supply system to engine **130** increases past a predetermined value or within a range of values. Other methods and systems may be implemented by work machine **100** to determine when a load occurs and the above examples are not intended to be limiting.

[**0047**] Returning to Step **350**, if engine control system **120** determines that work machine **100** is not experiencing a load while backing up (Step **350**; NO), the reverse control process continues at Step **370**, described below. On the other hand, if a load is detected (Step **350**; YES), engine control system **120** may be configured to disable the reverse control process to allow work machine **100** to deliver as much power (e.g., full power) required to handle the detected load (Step **360**). In one embodiment, engine control system **120** may temporarily disable the reverse control process such that it determines whether a directional shift to a forward travel direction has occurred (Step **340**). If so, the reverse control process ends. If forward directional shift is not detected, the reverse control process continues at Step **320**.

[**0048**] As explained, if engine control system **120** determines no load is experienced while traveling in the reverse direction, the speed of engine **130** may be adjusted in a manner consistent with the disclosed embodiments (Step **370**). For example, if engine control system **120** determines that the ground speed of work machine **100** is above the threshold value (e.g., 5 mph), system **120** may generate an engine control signal that reduces the speed of engine **130**, thus reducing the amount of power produced by engine **130**. In one embodiment, engine control system **120** may execute a program that determines the speed of which engine **130** should operate based on one or more parameters associated with work machine **100**. For example, engine control system **120** may adjust the speed of engine **130** based on the current speed of engine **130**, the current power produced by motor **150**, the current ground speed of work machine **100**, etc. Additionally, or alternatively, engine control system **120** may access a data structure stored in memory **214** (e.g., table, array, map, etc.) that includes data relationships between engine speed and these one or more other parameters. For instance, engine control system **120** may access a table stored in memory **214** that includes a performance map reflecting a data relationship between engine RPM to ground speeds, and a speed adjustment factor. Thus, for example, if engine **130** is running at 1950 RPM while work machine **100** is backing up at 6 mph, the map may indicate that the engine speed should be reduced to 1500 RPM, or by 450 RPM. Based on this information, engine control system **120** may generate an engine control signal that causes engine **130** to adjust its speed accordingly. Other methods and processes may be implemented by work machine **100** to adjust the operations of engine **130**.

[**0049**] In one embodiment, work machine **100** may be configured to disengage or adjust the transfer of power from

engine **130** to drive train **152** while performing the reverse control process. For example, work machine **100** may be configured to allow motor **150** to deliver the same amount, additional, or less, power to travel mechanism **155** when the speed of engine **130** is adjusted during the reverse control process. This enables work machine **100** to continue traveling at certain ground speeds (e.g., constant, increased, etc.) while reducing the speed of engine **130**. Such features reduce the amount of heat loss experienced by work machine **100** because of these reduced engine speeds. Further, implementing the disclosed embodiments allow heat load sharing because higher heat load from motor **150** is mitigated with lower heat load from engine **130**. Additionally, because engine **130** is operating at reduced speeds while in reverse, fuel consumption is reduced. Further, noise pollution may be reduced because of the reduced engine speed.

[**0050**] Also, the disclosed embodiments enable work machine **100** to improve its retarding performance because the reduced engine speed provides a greater potential to the engine overspeed limit during direction shift conditions. Overspeed limit is a value associated with the structural integrity of engine **130** and other components of work machine **100**. In certain embodiments, the overspeed limit represents the maximum (or near maximum) engine speed work machine **100** can handle when experiencing a directional shift. For example, when work machine **100** changes direction, the resulting kinetic energy from decelerating work machine **100** will have to be absorbed, stored, or dissipated. Thus, the greater the difference between the engine speed and overspeed, limit, the more kinetic energy engine **130** or other work machine **100** components can absorb when machine **100** experiences a directional shift to a forward direction. To better illustrate this concept, consider the following example. Work machine may be rated with an overspeed limit of 2500 RPM. Suppose, for example, that work machine **100** is traveling in a reverse direction while the engine speed is running at 2000 RPM. The difference between the overspeed limit (i.e., 2500 RPM) and the current engine speed (i.e., 2000 RPM) relates to an amount of kinetic energy work machine **100** or engine **130** can handle when the machine shifts to a forward direction (i.e., 500 RPM). Work machine **100** is able to increase the amount of kinetic energy by reducing the engine speed below 2000 rpm prior to the directional shift occurring.

[**0051**] FIG. **4** illustrates a flowchart of another exemplary reverse control process that takes overspeed limit into consideration. In this embodiment, engine control system **120** and/or control system **110** may be configured to detect when work machine **100** experiences a directional shift to reverse in a manner similar to that described in connection with Step **310** of FIG. **3** (Step **410**). Based on a detected directional shift, engine control system **120** receives data reflecting the change in traveling direction of work machine **100**.

[**0052**] Once such an indication is received, engine control system **120** may execute a reverse control program stored in memory **214**. In one embodiment, the reverse control program may perform a process that determines whether engine control system **120** is configured in a speed parameter mode, similar to that described above with respect to Step **320** of FIG. **3** (Step **420**). If engine control system **120** is not configured in a speed parameter mode (Step **420**; NO), the reverse control process continues after Step **470**, described below. On the other hand, if engine control system **120** is configured in a speed parameter mode (Step **420**; YES), system **120** may determine whether the ground speed of work machine **100** is above a predetermined threshold value while traveling in the reverse direction in a manner similar to that described in connection with Step **330** of FIG. **3** (Step **430**).

[**0053**] Once the ground speed of work machine **100** is determined, engine control system **120** may compare this speed to a predetermined ground speed threshold value that is programmed in memory **214**. If the ground speed of work machine **100** does not exceed the threshold value (Step **430**; NO), engine control system **120** may determine whether work machine **100** has experienced a directional shift to a forward direction (Step **440**) in a manner similar to that described above in connection with Step **340** of FIG. **3**. If no forward directional shift is detected (Step **440**; NO), the reverse control process continues at Step **420**. If, however, a directional shift to a forward direction is detected (Step **440**; YES), the reverse control process ends.

[**0054**] Referring back to Step **430**, if engine control system **120** determines that the ground speed of work machine **100** has exceeded the threshold value (Step **430**; YES), system **120** may compare the current engine speed of engine **130** to an overspeed limit stored in memory **214** (Step **450**). If the engine speed does not exceed, or is not within a predetermined range of, the overspeed limit (Step **460**; NO), the alternate reverse control process continues at Step **440**. On the other hand, if the engine speed exceeds, or is within a predetermined range of, the overspeed limit (Step **460**; YES), engine control system **120** may adjust the speed of engine **130** in a manner similar to that described in connection with Step **370** of FIG. **3** (Step **470**).

[**0055**] Thus, in certain embodiments, control system **120** may execute a process that determines the kinetic energy level of work machine **100** based on the overspeed limit and current engine speed of work machine **100**. Using the determined kinetic energy, control system **120** may adjust the speed of engine **130** to meet the determined kinetic energy level prior to or during directional shifts of work machine **100**.

INDUSTRIAL APPLICABILITY

[**0056**] In certain embodiments, an electric drive work machine may perform tasks that directional shifts to take place consistently over an extended period of time. For example, the work machine, such as a dozer or ripper type machine, may perform tasks that require the machine to repeatedly travel in reverse and forward while manipulating terrain or materials. Methods and systems consistent with the disclosed embodiments allow the work machine to increase its performance during these repeated reverse directional cycles. In certain embodiments, the work machine may selectively adjust the speed of its engine when it travels in a reverse direction. The work machine may be configured to use its electric motor to maintain the machine's ground speed while backing up and while the engine speed is reduced, thus increasing fuel economy, improving retarding performance, and reducing heat loss from the engine. In certain embodiments, the work machine may selectively disable certain features when the machine experiences loads while traveling in a reverse direction. Further, the work

machine may be configured to adjust engine speeds based on overspeed limits associated with the work machine or its components.

[0057] Although the disclosed embodiments have been described with respect to reverse directional shifts, other types of directional shifts may be considered and implemented. For example, certain embodiments may be applied to directional shifts from reverse to a forward direction.

[0058] As described, engine control system **120** may be configured to disable the reverse control process when the work machine experiences a load while traveling in reverse. An example of such a load is when work machine **100** is backing up a sloped terrain surface. In such conditions, work machine **100** may be configured to maintain or reduce the ground speed of work machine through the power produced by motor **150**. Further, when engine control system **120** determines that the speed of engine **130** may be reduced, the power provided by motor **150** may also be reduced based on one or more parameters associated with work machine **100** and/or the terrain surface on which the machine is traveling. For example, in situations where the terrain surface sloped downward, engine control system **120** may be configured to adjust the speed of engine **130** to reduce the amount of heat and power wasted when machine **100** backs down the declined slope. At the same time, in some embodiments, work machine **100** may be configured to reduce the power provided by motor **150** to reduce unnecessary heat losses while traveling in reverse.

[0059] The disclosed embodiments may be implemented in various environments and are not limited to work site environments. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the embodiments disclosed herein.

1-27. (canceled)

28. A method for controlling an electric drive machine including an engine and an electric motor that provides power to enable the machine to travel across a surface terrain at certain ground speeds, the method comprising:

detecting a reverse directional shift of the machine causing the machine to travel in a reverse direction; and

performing an engine speed reduction process that reduces a current speed of the engine based on the detected reverse directional shift without reducing a ground speed of the machine while traveling in the reverse direction.

29. The method of claim 28, wherein the method further includes:

determining whether the machine is experiencing a load while traveling in the reverse direction; and

disabling the engine speed reduction process when the machine is experiencing a load while traveling in the reverse direction.

30. The method of claim 28, further including:

determining whether the ground speed of the machine exceeds a predetermined threshold speed value; and

bypassing the engine speed reduction process when the ground speed of the machine does not exceed the predetermined threshold speed value.

31. The method of claim 30, further including:

determining whether the machine is experiencing a load while traveling in the reverse direction; and

disabling the engine speed reduction process when the machine is experiencing a load while traveling in the reverse direction.

32. The method of claim 29, wherein determining whether the machine is experiencing a load while traveling in the reverse direction includes:

determining that the machine is backing up on a sloped terrain surface.

33. The method of claim 29, wherein determining whether the machine is experiencing a load while traveling in the reverse direction includes:

determining that the machine is manipulating a load while traveling in the reverse direction, wherein manipulating the load includes at least one of pushing the load, pulling the load, and carrying the load.

34. The method of claim 28, wherein performing the engine speed reduction process includes:

determining an adjusted engine speed based on at least one of the current speed of the engine and the ground speed of the machine; and

generating a control signal that reduces the current speed of the engine to the adjusted engine speed.

35. The method of claim 34, wherein performing the engine speed reduction process further includes:

allowing the motor of the machine to produce sufficient power to at least maintain the ground speed of the machine while traveling in the reverse direction.

36. A method for controlling an electric drive machine including an engine and an electric motor that provides power to enable the machine to travel across a surface terrain at certain ground speeds, the method comprising:

detecting a directional shift of the machine causing the machine to operate in a new directional cycle that is different from a current directional cycle; and

performing an engine speed adjustment process that adjusts a current speed of the engine based on the detected directional shift without adjusting a ground speed of the machine during the new directional cycle.

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