



(11)

EP 4 579 045 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
02.07.2025 Bulletin 2025/27

(51) International Patent Classification (IPC):
E02F 9/20 ^(2006.01) **E02F 9/22** ^(2006.01)
E02F 3/42 ^(2006.01)

(21) Application number: **24855080.8**

(86) International application number:
PCT/CN2024/070105

(22) Date of filing: **02.01.2024**

(87) International publication number:
WO 2025/097581 (15.05.2025 Gazette 2025/20)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **LIU, Jian**
Xuzhou, Jiangsu 221004 (CN)
• **QIN, Haoliang**
Xuzhou, Jiangsu 221004 (CN)
• **XIA, Guanghao**
Xuzhou, Jiangsu 221004 (CN)

(30) Priority: **07.11.2023 CN 202311467067**

(74) Representative: **Ruttensperger Lachnit Trossin
Gomoll**
Patent- und Rechtsanwälte
PartG mbB
Arnulfstraße 58
80335 München (DE)

(71) Applicant: **JIANGSU XCMG STATE KEY
LABORATORY TECHNOLOGY
CO., LTD.**
Xuzhou Jiangsu 221004 (CN)

(54) **LOADER CONTROL METHOD, CONTROLLER, CONTROL SYSTEM, STORAGE MEDIUM AND
LOADER**

(57) The present disclosure provides a method and system for controlling a loader, a controller, a storage medium and a loader, which relates to the field of loaders. The control method includes: determining whether a

wheel of the loader slips when the loader is performing a shoveling and digging operation; and controlling a drive motor to reduce output torque and controlling a boom to lift in a case where the wheel of the loader slips.

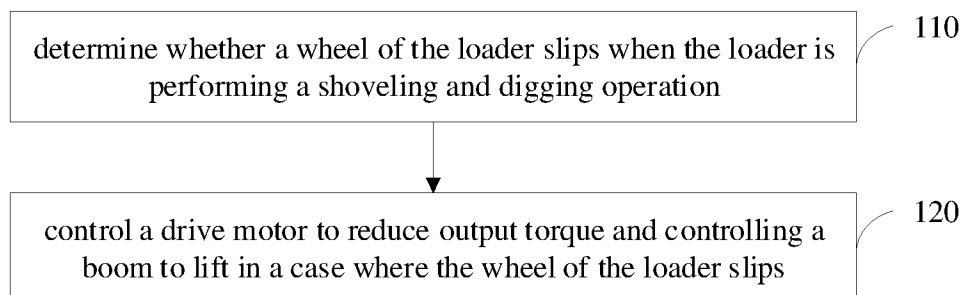


FIG. 1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present disclosure is based on and claims priority of Chinese application for invention 202311467067.1, filed on November 07, 2023, the disclosure of which is hereby incorporated into this disclosure by reference in its entirety.

TECHNICAL FIELD

[0002] This disclosure relates to the field of loaders, particularly to a method and system for controlling a loader, a controller, a storage medium, and a loader.

BACKGROUND

[0003] The loader is a large construction machinery equipment, which is commonly used in construction sites, mining sites, ports and other places. Using a bucket and a boom mounted at the front end of the loader, the loader loads materials such as soil, sand and gravel for earthwork excavation, transport, loading and unloading processes.

[0004] In related technologies, the transmission systems of wheel loaders are generally driven by internal combustion engines. However, with the development of new energy technologies and the increasing emphasis on energy efficiency and environmental protection in various countries, Full electric loaders with electric motors as the drive systems have been developed and mass-produced by construction machinery manufacturers. The full electric loaders are increasingly favored by the market due to their advantages of low operating cost, zero pollution, low noise, energy conservation and environmental protection, which have a very wide market application prospect.

[0005] When shoveling and digging with a traditional loader driven by an internal combustion engine, due to the load resistance, the operator often instinctively presses the accelerator pedal to obtain more shoveling force, resulting in wheel slip as a common and normal phenomenon. However, in the case of The full electric loaders, wheel slip can cause the engine controller to trigger a fault and stop the vehicle. In severe cases, it may even require a power shutdown and restart to recover, which can seriously affect the entire operation of the loader.

SUMMARY

[0006] According to an aspect of the present disclosure, there is provided a method for controlling a loader, comprising: determining whether a wheel of the loader slips when the loader is performing a shoveling and digging operation; and controlling a drive motor to reduce output torque and controlling a boom to lift in a case

where the wheel of the loader slips.

[0007] In some embodiments, controlling a gearbox to downshift to obtain a decrease in travel speed in response to a shoveling and digging operation request, in a case where the wheel of the loader still slips after reducing the output torque of the drive motor and lifting the boom.

[0008] In some embodiments, controlling the boom to descend before controlling the gearbox to downshift; and controlling the drive motor to reduce the output torque and controlling the boom to lift, in a case where the wheel of the loader still slips after the gearbox is controlled to downshift and the number of drive motor output torque reductions and boom lifts is less than a first threshold.

[0009] In some embodiments, the controlling the drive motor to reduce output torque comprises: controlling the drive motor to reduce the output torque to a first torque; and controlling the drive motor to reduce the output torque to a torque threshold, in a case where the wheel of the loader still slips after the output torque of the drive motor is reduced to the first torque and the boom is lifted to a highest position.

[0010] In some embodiments, the controlling the drive motor to reduce the output torque to a first torque comprises: determining a torque reduction coefficient according to a slip rate of the wheel; determining the first torque according to the torque reduction coefficient and a requested torque; and reducing the output torque of the drive motor according to the first torque.

[0011] In some embodiments, the controlling the boom to lift comprises: controlling a boom cylinder to extend to lift the boom based on an opening current of a control valve of the boom cylinder.

[0012] In some embodiments, controlling the loader to perform an unloading operation in response to an unloading request, in a case where the loader still has wheel slip after reducing the output torque of the drive motor and lifting the boom.

[0013] In some embodiments, the determining whether the wheel of the loader slips when the loader is performing the shoveling and digging operation comprises: obtaining an actual travel speed and a wheel speed of the loader; determining a slip rate of the wheel based on the actual travel speed and the wheel speed; determining that the wheel of the loader slips in a case where the slip rate is greater than a second threshold; and determining that the wheel of the loader does not slip in a case where the slip rate is less than or equal to the second threshold.

[0014] In some embodiments, obtaining the actual travel speed of the loader comprises: obtaining the actual travel speed using a global positioning system (GPS) sensor; and obtaining the wheel speed comprises: obtaining the wheel speed using a wheel speed sensor; or determining the wheel speed based on a gear signal of the loader.

[0015] According to another aspect of the present disclosure, there is further provided a loader controller,

comprising: a determination module configured to determine whether a wheel of the loader slips when the loader is performing a shoveling and digging operation; and a control module configured to control a drive motor to reduce output torque and control a boom to lift in a case where the wheel of the loader slips.

[0016] According to another aspect of the present disclosure, there is further provided a loader controller, comprising: a memory; and a processor coupled to the memory, the processor configured to perform the method for controlling a loader described above based on instructions stored in the memory.

[0017] According to a further aspect of the present disclosure, there is further provided a system for controlling a loader, comprising: the loader controller described above; an electric drive system configured to control a motor to reduce torque based on an instruction from the loader controller to reduce the output torque of the drive motor; and a working hydraulic device configured to control a boom cylinder to extend to lift the boom according to an instruction from the loader controller to control the boom to lift.

[0018] In some embodiments, a gearbox actuator configured to downshift a gearbox based on an instruction from the loader controller to downshift the gearbox; a global positioning system (GPS) sensor configured to send a signal related to an actual travel speed of the loader to the loader controller; or a wheel speed sensor configured to send a signal related to a wheel speed to the loader controller.

[0019] According to another aspect of the present disclosure, there is further provided a loader, comprising: a loader controller described above; or the system for controlling the loader described above.

[0020] According to another aspect of the present disclosure, there is further provided a computer readable storage medium stored thereon computer program instructions that, when executed by a processor, implement the method for controlling loader described above.

[0021] Other features and advantages of the present invention will become apparent from the following detailed description of exemplary embodiments of the present disclosure with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The accompanying drawings, which are incorporated in and constitute a portion of this specification, illustrate embodiments of the present disclosure and, together with the description, serve to explain the principles of the present disclosure.

[0023] The present disclosure will be more clearly understood from the following detailed description with reference to the accompanying drawings, in which:

FIG. 1 is a flowchart of a method for controlling a loader according to some embodiments of the pre-

sent disclosure;

FIG. 2 is a flowchart of a method for controlling a loader according to other embodiments of the present disclosure;

FIG. 3 is a flowchart of a method for controlling a loader according to other embodiments of the present disclosure;

FIG. 4 is a flowchart of a method for controlling a loader according to other embodiments of the present disclosure;

FIG. 5 is a schematic structural diagram of a loader controller according to some embodiments of the present disclosure;

FIG. 6 is a schematic structural diagram of a loader controller according to other embodiments of the present disclosure;

FIG. 7 is a schematic structural diagram of a system for controlling a loader according to some embodiments of the present disclosure;

FIG. 8 is a schematic structural diagram of a system for controlling a loader according to other embodiments of the present disclosure.

DETAILED DESCRIPTION

[0024] Various exemplary embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings. Notice that, unless otherwise specified, the relative arrangement, numerical expressions and values of the components and steps set forth in these examples do not limit the scope of the disclosure.

[0025] At the same time, it should be understood that, for ease of description, the dimensions of the various parts shown in the drawings are not drawn to actual proportions.

[0026] The following description of at least one exemplary embodiment is in fact merely illustrative and is in no way intended as a limitation to the disclosure, its application or use.

[0027] Techniques, methods, and apparatus known to those of ordinary skill in the relevant art may not be discussed in detail, but where appropriate, these techniques, methods, and apparatuses should be considered as part of the specification.

[0028] Of all the examples shown and discussed herein, any specific value should be construed as merely illustrative and not as a limitation. Thus, other examples of exemplary embodiments may have different values.

[0029] Notice that, similar reference numerals and letters are denoted by the like in the accompanying drawings, and therefore, once an item is defined in a drawing, there is no need for further discussion in the accompanying drawings.

[0030] For a clear understanding of the object of the present disclosure, its technical solution and advantages, the present disclosure will be further described in detail below in conjunction with the accompanying

drawings and embodiments.

[0031] Related technologies often rely on manual operator intervention to prevent wheel slip on The full electric loaders, which can add complexity to the operation and make it difficult to adapt to road conditions and other factors in real time. Thus, preventing or reducing the wheel slips when the loader is performing an operation and improving the stability and safety of shoveling and digging operations is a pressing issue that needs to be addressed today.

[0032] FIG. 1 is a flowchart of a method for controlling a loader according to some embodiments of the present disclosure, which is performed by a loader controller, such as a safety control unit.

[0033] In step 110, it is determined whether a wheel of the loader slips when the loader is performing a shoveling and digging operation.

[0034] In some embodiments, the loader is a wheel loader, such as an electric wheel loader. The loader comprises a gearbox.

[0035] In some embodiments, whether the wheel slips is determined based on a slip rate of the loader' wheel. For example, in a case where the slip rate is greater than a threshold, it indicates that the loader is experiencing wheel slip, and a loader controller should adopt a corresponding control strategy to prevent this situation.

[0036] In step 120, a drive motor is controlled to reduce output torque and a boom is controlled to lift in a case where the wheel of the loader slips.

[0037] In some embodiments, the output torque of the drive motor is controlled by an electric drive system. For example, the electric drive system comprises a motor controller and a drive motor. By adjusting the torque output of the motor controller, the output power of the drive motor is reduced to achieve a reduction in the output torque of the drive motor.

[0038] When the loader is excavating a load, if it fails to move forward and the wheels start to slip, the wheels rotate will relatively quickly and the driving force on the wheels is greater than the reaction force of the ground on the wheels. Therefore, the motor torque can be reduced to decrease the driving force on the wheels and then to change the friction between the wheels and the ground, to reduce the risk of wheel slip and prevent wheel wear.

[0039] In some embodiments, the lifting of the boom is controlled by a working hydraulic system. After the boom is lifted, the resistance between the bucket and the load is reduced, thereby reducing the risk of wheel slip and ensuring that no wheel slip occurs as the loader excavates the load.

[0040] In the above embodiments, by controlling the drive motor to reduce the output torque and controlling the controlling a boom to lift, the risk of wheel slip can be reduced, thereby improving the operational efficiency and safety of the loader in various terrains and working conditions.

[0041] FIG. 2 is a flowchart of a method for controlling a loader according to other embodiments of the present

disclosure that is performed by a loader controller.

[0042] In step 110, it is determined whether a wheel of the loader slips when the loader is performing a shoveling and digging operation.

5 **[0043]** In step 120, a drive motor is controlled to reduce output torque and a boom is controlled to lift in a case where the wheel of the loader slips.

[0044] In some embodiments, the drive motor is controlled to reduce its output torque to a first torque; the
10 the drive motor is controlled to reduce the output torque to a torque threshold in a case where the wheel of the loader still slips after the output torque of the drive motor is reduced to the first torque and the boom is lifted to a highest position.

15 **[0045]** In some embodiments, a torque reduction coefficient is determined according to the slip rate of the wheel; the first torque is determined according to the torque reduction coefficient and a requested torque; and the output torque of the drive motor is reduced
20 according to the first torque.

[0046] In this embodiment, a constraint is applied to the operator's torque request. For example, instead of responding fully to the operator's throttle opening request, the current torque is multiplied by a torque reduction coefficient to prevent the operator from instinctively stepping on the accelerator and exacerbating wheel slip. After determining the slip rate of the wheel, a current torque reduction coefficient is determined based on the correspondence between the slip rate and the torque reduction coefficient, which can be obtained by consulting a table. For example, the value of the torque reduction coefficient is greater than or equal to 40% and less than 100%.

[0047] In some embodiments, a boom cylinder is controlled to extend to lift the boom based on an opening current of a control valve of the boom cylinder.

[0048] For example, the loader controller issues a lift control instruction to the boom. For an electromagnetic proportional valve of the boom cylinder, its input current is the opening current of the valve, ensuring that the boom can rise slowly and avoiding situations where the lift speed is too fast. The electromagnetic proportional valve can be opened only when the current input to the electromagnetic proportional valve reaches a predetermined current value, i.e., the opening current is the minimum current with which the electromagnetic proportional valve can be opened. Since the current is not applied to the electromagnetic proportional valve from 0, the opening time of the electromagnetic proportional valve can be shortened.
35
40
45
50

[0049] In some embodiments, the boom is lifted to its highest position. It is determined whether the boom has been lifted to the highest position by checking whether the boom cylinder is fully extended.

55 **[0050]** In step 230, it is determined whether wheel of the loader still slips.

[0051] In step 240, a gearbox is controlled to downshift to obtain a decrease in travel speed in response to a

shoveling and digging operation request, in a case where the wheel of the loader still slips.

[0052] In some embodiments, the boom is controlled to descend before the gearbox is controlled to downshift. By controlling the boom to lift in step 120, the bucket is separated from the load. To resume excavation, the boom must be lowered to bring the bucket into contact with the load.

[0053] In some embodiments, in a case where the output torque of the drive motor decreases to a torque threshold and the boom cylinder is fully extended, if the wheel of the loader still slips, a signal is output on a display screen to prompt the operator for options of "unload" and "re-excavate". If the operator selects the "re-excavate" option, the loader controller sends a signal to a gearbox actuator and automatically outputs a descent control signal for the boom. The gearbox actuator shifts to neutral and the boom descends. The gearbox actuator then operates on a reverse signal to move the loader a certain distance and returns to neutral. The loader controller shifts to a lower gear based on the previous forward gear and outputs a shift signal to the gearbox actuator to reduce the travel speed of the loader.

[0054] in a case where the wheel of the loader slips, there is a lot of idle power while the wheels slip. Therefore, by downshifting to reduce the travel speed, it is possible to reduce the energy wasted as idle power during wheel slipping, reduce the energy consumption required for material transport, and save operating costs. In addition, as vehicle speed decreases, the motor's output torque increases, resulting in greater power output. In a case where the loader re-excavates, it hopes to start with more power, and so it hopes to increase the torque to allow the loader to resume excavation.

[0055] In the above embodiment, by adjusting the torque output of the loader in real time, changing the resistance between the bucket and the load, and adjusting the travel speed of the loader, the risk of wheel slip is reduced. In addition, by adjusting the travel speed of the loader, the occurrence of motor controller failure can be reduced, thus ensuring smooth operation of the loader. Additionally, this embodiment reduces the risk of tire wear and machine damage, which can reduce maintenance and downtime and improve the efficiency of the loader.

[0056] In some embodiments, in a case where the wheel of the loader still slips after the gearbox is controlled to downshift and the number of drive motor output torque reductions or the number of boom lifts is less than a first threshold, the drive motor is controlled to reduce its output torque and the boom is controlled to lift.

[0057] For example, in a case where the loader has already performed an anti-slip operation, i.e., the motor torque has been limited, the boom has been lifted, and the gearbox has been downshifted once, the loader can be allowed to resume excavation where, if wheel slip still occurs, another torque limit and boom lift will be applied. If there is still wheel slip in this case, there is no need to attempt to another slippage elimination operation again.

At this point, the operator can drive the loader to an unloading location to perform an unloading operation. The cycle of shoveling and unloading with wheel slip is completed, ensuring that the overall efficiency of the system is not greatly affected.

[0058] In some embodiments, in a case where the wheel of the loader still slips after reducing the output torque of the drive motor and lifting the boom, the loader is controlled to perform an unloading operation in response to an unloading request.

[0059] For example, in a case where the output torque of the drive motor decreases to a torque threshold and the boom cylinder is fully extended, if the loader still has wheel slip, a signal is output on a display screen to prompt the operator for "unload" or "re-excavate" options. If the operator selects the "unload" option, the operator will drive the loader to an unloading location to perform the unloading operation, and this shoveling and unloading operation is completed.

[0060] FIG. 3 is a flowchart of a method for controlling a loader according to other embodiments of the present disclosure that is performed by the loader controller.

[0061] In step 310, an actual travel speed and a wheel speed are obtained for the loader.

[0062] In some embodiments, the actual travel speed is obtained using a global positioning system (GPS) sensor. The GPS sensor is mounted on the top of the loader to measure an actual travel speed V1 (Km/h) of the loader. In a case where the GPS sensor transmits a frequency signal, the manufacturer will provide a conversion relationship between frequency and vehicle speed in advance. After receiving the frequency signal, the loader controller converts the frequency signal to an actual vehicle speed.

[0063] In some embodiments, the wheel speed is obtained using a wheel speed sensor. The wheel speed sensor is mounted on one side of the wheel where the steering rod is located and is, for example, a photoelectric encoder type sensor. The circular surface of the wheel hub is divided into X equal parts, each with a reflective sticker. The wheel speed sensor senses the number of reflective stickers as the wheel rotates and then sends it to the loader controller as a count, such as a frequency signal f2. The loader controller obtains a wheel speed V2 according to the formula $V2 \text{ (Km/h)} = 2 * 3.14 * R * 3.6 * f2 / X$, wherein R is the tire rolling radius and f2 is the frequency value sent by the wheel speed sensor. The larger the X value, the more accurate the calculated V2. In some embodiments, the value of X is, for example, 50.

[0064] In some embodiments, the wheel speed is determined based on a gear signal of the loader. In this embodiment, instead of providing the wheel speed sensor, gear information obtained from the gearbox is used to determine the wheel speed. For example, the wheel speed $V2 = 0.377 * n * R / (ig * i0)$, wherein n is the motor's rotation speed, R is the tire rolling radius, ig is the gear ratio of the gearbox at a current gear, and i0 is the overall reduction ratio of the rear axle. The loader obtains n via a

CAN (Controller Area Network) bus.

[0065] The loader controller can obtain a gear ratio of each gear of the gearbox and a motor rotation speed. Using the gear ratio of each gear and the motor rotation speed, an output shaft rotation speed of the gearbox can be obtained. Based on the vehicle structure and the rear axle reduction ratio, the wheel speed can be calculated.

[0066] In this step, the GPS sensor and wheel speed sensor convert the detected data into electrical signals and send the electrical signals to the loader controller for analysis. Since the GPS sensor and wheel speed sensor can be affected by vibration and excitation, signal filtering methods and data processing techniques are required to reduce interference.

[0067] In step 320, a slip rate of the wheel is determined based on the actual travel speed and the wheel speed.

[0068] In some embodiments, the slip rate of the wheel is the ratio of a difference between the wheel speed and the actual travel speed to the wheel speed.

[0069] In step 330, it is determined that the wheel of the loader slips in a case where the slip rate is greater than a second threshold.

[0070] For example, the slip rate of the wheel $Sr = (V2 - V1)/V2$, which generally does not exceed 20%. In a case where Sr is greater than 20%, the loader controller determines that the loader is experiencing wheel slip and adopts an appropriate control strategy to prevent wheel slip.

[0071] In step 340, it is determined that the wheel of the loader does not slip in a case where the slip rate is less than or equal to the second threshold.

[0072] In the above embodiment, based on the actual travel speed and the wheel speed of the loader, a signal representing the wheels losing grip on the ground is detected and the slip rate of the wheel is calculated. The calculated slip rate of the wheel is compared to a threshold value to determine whether the loader is experiencing wheel slip.

[0073] FIG. 4 is a flowchart of a method for controlling a loader according to other embodiments of the present disclosure.

[0074] In step 410, relevant signals are collected.

[0075] For example, data is collected from various sensors.

[0076] In step 420, smoothness processing is performed on the signals.

[0077] In step 430, signal acquisition and calculation are performed.

[0078] In step 440, the slip rate of the wheel is calculated.

[0079] In step 450, it is determined whether the wheel of the loader slips; if so, step 4140 is executed; otherwise, step 460 is executed.

[0080] In step 460, the torque is limited and the boom is controlled to lift slowly.

[0081] In step 470, it is determined whether an anti-slip operation has been performed; if so, step 4140 is executed; otherwise, step 480 is executed.

[0082] In step 480, it is determined whether the slipping phenomenon has been eliminated; if so, step 4140 is executed; otherwise, step 490 is executed.

[0083] In step 490, the torque is reduced to a torque threshold and the boom cylinder is fully extended.

[0084] In step 4100, it is determined whether the slipping phenomenon has been eliminated; if so, step 4140 is executed; otherwise, step 4110 is executed.

[0085] In step 4110, a signal is output on the display screen to prompt the operator for "unload" and "re-excavate" options. If "unload" option is selected, step 4140 is executed; if "re-excavate" option is selected, step 4120 is executed.

[0086] In step 4120, the gearbox is downshifted and the travel speed is reduced, then excavation is resumed.

[0087] The gearbox actuator returns to neutral and the boom descends. The gearbox actuator operates on a reverse signal to move the loader a certain distance and returns to neutral. Thereafter, the gearbox is downshifted to a lower gear based on the previous forward gear, so that the travel speed of the loader is reduced to resume excavation. If there is no subsequent wheel slip, this indicates that the slip rate of the wheel has returned to normal and the loader is performing normal shoveling and unloading operations.

[0088] In step 4130, it is determined whether the slipping phenomenon has been eliminated; if so, step 4140 is executed; otherwise, step 460 is executed.

[0089] In step 4140, the operator drives the loader to unload at an unloading location, and the shoveling and unloading operation is completed.

[0090] In the above embodiment, the motor control cooperates with the boom cylinder, and a gear control measure is adopted to prevent wheel slip. The whole process can operate automatically to assist the operator in safe and reliable operation, reduce the operator's operation intensity, improve the stability and reliability of the whole system, capable of reducing the risk of accidents, and capable of achieving the best loader operating state. It can meet the operational needs of loaders of different sizes and types, and has a wide range of application prospects.

[0091] FIG. 5 is a schematic structure diagram of a loader controller according to some embodiments of the present disclosure, which comprises a determination module 510 and a control module 520.

[0092] The determination module 510 is configured to determine whether a wheel of the loader slips when the loader is performing a shoveling and digging operation.

[0093] In some embodiments, the actual travel speed and the wheel speed of the loader are acquired; the slip rate of the wheel is determined based on the actual travel speed and the wheel speed; it is determined that the wheel of the loader slips in a case where the slip rate is greater than the second threshold; and it is determined that the wheel of the loader does not slip in a case where the slip rate is less than or equal to the second threshold.

[0094] For example, the actual travel speed is obtained

using a GPS sensor. The wheel speed is obtained using the wheel speed sensor; or the wheel speed is determined based on the gear signal of the loader.

[0095] The control module 520 is configured to control a drive motor to reduce output torque and controlling a boom to lift in a case where the wheel of the loader slips.

[0096] In some embodiments, the drive motor is controlled to reduce the output torque to a first torque; the drive motor is controlled to reduce the output torque to a torque threshold, in a case where the wheel of the loader still slips after the output torque of the drive motor is reduced to the first torque and the boom is lifted to a highest position.

[0097] A torque reduction coefficient is determined according to a slip rate of the wheel; the first torque is determined according to the torque reduction coefficient and a requested torque; and the output torque of the drive motor is reduced according to the first torque.

[0098] In some embodiments, the control module 520 is further configured to control a gearbox to downshift to obtain a decrease in travel speed in response to a shoveling and digging operation request, in a case where the wheel of the loader still slips after reducing the output torque of the drive motor and lifting the boom.

[0099] The control module 520 is further configured to control the boom to descend before controlling the gearbox to downshift; and control the drive motor to reduce the output torque and controlling the boom to lift, in a case where the wheel of the loader still slips after the gearbox is controlled to downshift and the number of drive motor output torque reductions and boom lifts is less than a first threshold.

[0100] In some embodiments, a boom cylinder is controlled to extend to lift the boom based on an opening current of a control valve of the boom cylinder. Thus, the risk of tire wear and machine damage can be reduced, which can reduce maintenance and downtime and improve the efficiency of the loader.

[0101] In the above embodiment, in a case where the loader experiences wheel slip, the drive motor is controlled to reduce the output torque and the boom is controlled to lift, which solves the problem of wheel slip that may occur on an Full electric loader during excavation, thereby reducing the occurrence of motor controller failure and ensuring smooth operation of the loader.

[0102] FIG. 6 is a schematic structural diagram of a loader controller according to other embodiments of the present disclosure. The loader controller 600 comprises a memory 610 and a processor 620, wherein the memory 610 may be a magnetic disk, flash memory or any other non-volatile storage medium. The memory 610 is configured to store instructions of the above embodiment. The processor 620 is coupled to the memory 610 and may be implemented as one or more integrated circuits, such as a microprocessor or microcontroller. The processor 620 is configured to execute the instructions stored in the memory.

[0103] In some embodiments, the processor 620 is

coupled to the memory 610 via a bus 630. The controller 600 may be further connected to an external storage device 650 through a storage interface 640 to access external data, and may be further connected to a network or another computer system (not shown) through a network interface 660, which will not be described in detail herein.

[0104] In this embodiment, data and instructions are stored in the memory and processed by the processor to reduce the risk of wheel slip and improve the operational efficiency and safety of the loader in various terrains and working conditions.

[0105] FIG. 7 is a schematic structural diagram of a system for controlling a loader according to some embodiments of the present disclosure. The loader control system comprises the loader controller 600 of the above embodiment, as well as an electric drive system 710 and a working hydraulic device 720. The loader controller 600 serves as a signal processing device of the entire system and is the main device for managing and processing data provided by sensors. The loader controller 600 has been described in detail in the above embodiment and will not be further described here.

[0106] The electric drive system 710 is configured to control a motor to reduce the torque based on an instruction from the loader controller to reduce the output torque of the drive motor.

[0107] The electric drive system consists of a motor and a motor controller, which is configured to provide power for the loader. The motor controller responds to the torque request signal sent by the loader controller via a CAN bus and feeds back a motor speed to the loader controller via the CAN bus. The output shaft of the motor is connected to the input shaft of a gearbox via a spline to transmit power to the front and rear axles to drive the vehicle.

[0108] The working hydraulic device 720 is configured to control a boom cylinder to extend to lift the boom according to an instruction from the loader controller to control the boom to lift.

[0109] The working hydraulic device is equipped with a multi-way valve that receives a current signal from the loader controller. By controlling the degree of opening of the valve, the flow rate of the hydraulic system is controlled to achieve the extension and retraction of a boom cylinder and a bucket cylinder. The working hydraulic device and a steering hydraulic system share a large displacement gear pump.

[0110] In the above embodiment, the electric drive system and the working hydraulic device cooperate with each other to automatically adjust the torque output and boom lifting of the loader, thereby reducing the risk of wheel slip and the risk of accidents, minimizing the occurrence of engine controller failure, and ensuring smooth operation of the loader.

[0111] In some embodiments of the present disclosure, as shown in FIG. 8, the system for controlling the loader further comprises a gearbox actuator 810 downshift the

gearbox based on an instruction from the loader controller to downshift the gearbox.

[0112] The full electric loaders usually do not have gearboxes that can be found in traditional fuel loaders. Instead, a transmission system is directly driven by an electric motor, which is structurally simple and easy to implement. In this embodiment, the gearbox is introduced into the control system to adjust and optimize the efficiency allocation of the motor. By adjusting the speed ratio, the operating point of the motor is in a high-efficiency range for more situations, which can save motor cost, improve performance advantages, and better meet the requirements of climbing. Adjusting the speed and the torque output of the loader through the gearbox not only gives the loader more flexible speed adjustment capabilities, but also improves transmission efficiency, making power distribution and utilization more flexible and efficient.

[0113] In some embodiments, the system for controlling the loader further comprises a GPS sensor 820 configured to send a signal related to an actual travel speed of the loader to the loader controller.

[0114] The GPS sensor is mounted on the top of the loader to obtain the actual travel speed of the loader, and sends the obtained data to the loader controller to determine whether the wheel of the loader slips. The GPS sensor can also transmit a frequency signal that has a corresponding relationship with the vehicle speed. Based on this correspondence, the loader controller can evaluate the actual travel speed of the loader.

[0115] In some embodiments, the system for controlling the loader further comprises a wheel speed sensor 830 configured to send a signal related to the wheel speed to the loader controller.

[0116] The wheel speed sensor is mounted on one side of the wheel to obtain a real-time wheel speed and send the obtained data to the loader controller to determine whether the wheel of the loader slips.

[0117] By determining whether the wheel of the loader slips and applying an appropriate control strategy when wheel slip occurs, the risk of wheel slip, tire wear and machine damage can be reduced, thereby reducing maintenance and downtime and improving the efficiency of the loader. In addition, the use of intelligent control algorithms and real-time adjustment of motor torque output can reduce energy waste caused by idle power during slipping, reduce energy consumption for material transport, and save operating costs.

[0118] In other embodiments of the present disclosure, a loader is also provided, which is an electric loader, specifically a wheeled electric loader. The loader comprises the loader controller or the system for controlling the loader described in the above embodiments, which can prevent or reduce wheel slip, improve the loader's traction and increase its stability.

[0119] In other embodiments, there is provided a computer-readable storage medium stored thereon computer program instructions that, when executed by a pro-

cessor, implement the steps of the method of the above embodiment. One skilled in the art should understand that, the embodiments of the present disclosure may be provided as a method, an apparatus, or a computer program product. Therefore, embodiments of the present disclosure can take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment containing both hardware and software elements. Moreover, the present disclosure may take the form of a computer program product embodied on one or more computer-usable non-transitory storage media (comprising but not limited to disk storage, CD-ROM, optical storage device, etc.) having computer-usable program code embodied therein.

[0120] The present disclosure is described with reference to flowcharts and/or block diagrams of methods, apparatuses (systems) and computer program products according to embodiments of the present disclosure. It should be understood that each process and/or block in the flowcharts and/or block diagrams, and combinations of the processes and/or blocks in the flowcharts and/or block diagrams may be implemented by computer program instructions. The computer program instructions may be provided to a processor of a general purpose computer, a special purpose computer, an embedded processor, or other programmable data processing apparatus to generate a machine such that the instructions executed by a processor of a computer or other programmable data processing apparatus to generate means implementing the functions specified in one or more flows of the flowcharts and/or one or more blocks of the block diagrams.

[0121] The computer program instructions may also be stored in a computer readable storage device capable of directing a computer or other programmable data processing apparatus to operate in a specific manner such that the instructions stored in the computer readable storage device produce an article of manufacture including instruction means implementing the functions specified in one or more flows of the flowcharts and/or one or more blocks of the block diagrams.

[0122] These computer program instructions can also be loaded onto a computer or other programmable device to perform a series of operation steps on the computer or other programmable device to generate a computer-implemented process such that the instructions executed on the computer or other programmable device provide steps implementing the functions specified in one or more flows of the flowcharts and/or one or more blocks of the block diagrams.

[0123] According to some embodiments of the present disclosure, there is further provided a computer program, comprising: instructions that, when executed by a processor, cause the processor to execute the method for controlling loader described above.

[0124] Heretofore, the present disclosure has been described in detail. In order to avoid obscuring the concepts of the present disclosure, some details known in the

art are not described. Based on the above description, those skilled in the art can understand how to implement the technical solutions disclosed herein.

[0125] Although some specific embodiments of the present disclosure have been described in detail by way of example, those skilled in the art should understand that the above examples are only for the purpose of illustration and are not intended to limit the scope of the present disclosure. It should be understood by those skilled in the art that the above embodiments may be modified without departing from the scope and spirit of the present disclosure. The scope of the disclosure is defined by the following claims.

Claims

1. A method for controlling a loader, comprising:

determining whether a wheel of the loader slips when the loader is performing a shoveling and digging operation; and
controlling a drive motor to reduce output torque and controlling a boom to lift in a case where the wheel of the loader slips.

2. The method for controlling the loader according to claim 1, further comprising:

controlling a gearbox to downshift to obtain a decrease in travel speed in response to a shoveling and digging operation request, in a case where the wheel of the loader still slips after reducing the output torque of the drive motor and lifting the boom.

3. The method for controlling the loader according to claim 2, further comprising:

controlling the boom to descend before controlling the gearbox to downshift; and
controlling the drive motor to reduce the output torque and controlling the boom to lift, in a case where the wheel of the loader still slips after the gearbox is controlled to downshift and the number of drive motor output torque reductions and boom lifts is less than a first threshold.

4. The method for controlling the loader according to any one of claims 1 to 3, wherein the controlling the drive motor to reduce output torque comprises:

controlling the drive motor to reduce the output torque to a first torque; and
controlling the drive motor to reduce the output torque to a torque threshold, in a case where the wheel of the loader still slips after the output torque of the drive motor is reduced to the first torque and the boom is lifted to a highest position.

5. The method for controlling the loader according to claim 4, wherein the controlling the drive motor to reduce the output torque to a first torque comprises:

determining a torque reduction coefficient according to a slip rate of the wheel;
determining the first torque according to the torque reduction coefficient and a requested torque; and
reducing the output torque of the drive motor according to the first torque.

6. The method for controlling the loader according to any one of claims 1 to 5, wherein the controlling the boom to lift comprises:

controlling a boom cylinder to extend to lift the boom based on an opening current of a control valve of the boom cylinder.

7. The method for controlling the loader according to any one of claims 1 to 6, further comprising:

controlling the loader to perform an unloading operation in response to an unloading request, in a case where the loader still has wheel slip after reducing the output torque of the drive motor and lifting the boom.

8. The method for controlling the loader according to any one of claims 1 to 7, wherein the determining whether the wheel of the loader slips when the loader is performing the shoveling and digging operation comprises:

obtaining an actual travel speed and a wheel speed of the loader;
determining a slip rate of the wheel based on the actual travel speed and the wheel speed;
determining that the wheel of the loader slips in a case where the slip rate is greater than a second threshold; and
determining that the wheel of the loader does not slip in a case where the slip rate is less than or equal to the second threshold.

9. The method for controlling the loader according to claim 8, wherein:

obtaining the actual travel speed of the loader comprises:

obtaining the actual travel speed using a global positioning system (GPS) sensor; and
obtaining the wheel speed comprises:

obtaining the wheel speed using a wheel speed sensor; or
determining the wheel speed based on a gear signal of the loader.

10. A loader controller, comprising:

a determination module configured to determine whether a wheel of the loader slips when the loader is performing a shoveling and digging operation; and
 a control module configured to control a drive motor to reduce output torque and control a boom to lift in a case where the wheel of the loader slips.

instructions that, when executed by a processor, cause the processor to perform the method for controlling loader according to any one of claims 1 to 9.

11. A loader controller, comprising:

a memory; and
 a processor coupled to the memory, the processor configured to, based on instructions stored in the memory, carry out the method for controlling loader according to any one of claims 1 to 9.

12. A system for controlling a loader, comprising:

the loader controller according to claim 10 or 11;
 an electric drive system configured to control a motor to reduce torque based on an instruction from the loader controller to reduce the output torque of the drive motor; and
 a working hydraulic device configured to control a boom cylinder to extend to lift the boom according to an instruction from the loader controller to control the boom to lift.

13. The system for controlling the loader according to claim 12, further comprising at least one of

a gearbox actuator configured to downshift a gearbox based on an instruction from the loader controller to downshift the gearbox;
 a global positioning system (GPS) sensor configured to send a signal related to an actual travel speed of the loader to the loader controller; or
 a wheel speed sensor configured to send a signal related to a wheel speed to the loader controller.

14. A loader, comprising:

the loader controller according to claim 10 or 11;
 or
 the system for controlling the loader according to claim 12 or 13.

15. A computer-readable storage medium stored thereon computer program instructions that, when executed by a processor, implement the method for controlling loader according to any one of claims 1 to 9.**16.** A computer program, comprising:

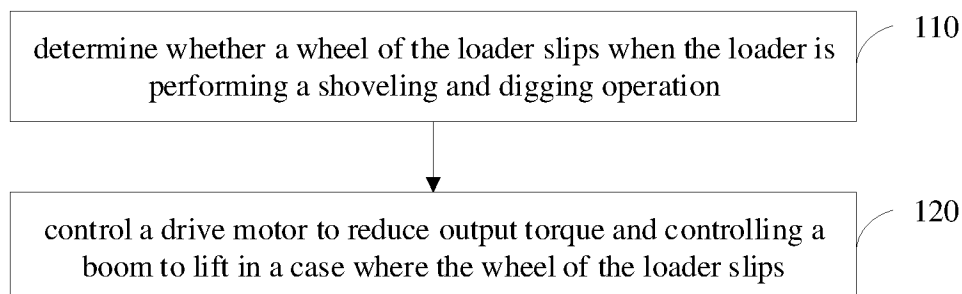


FIG. 1

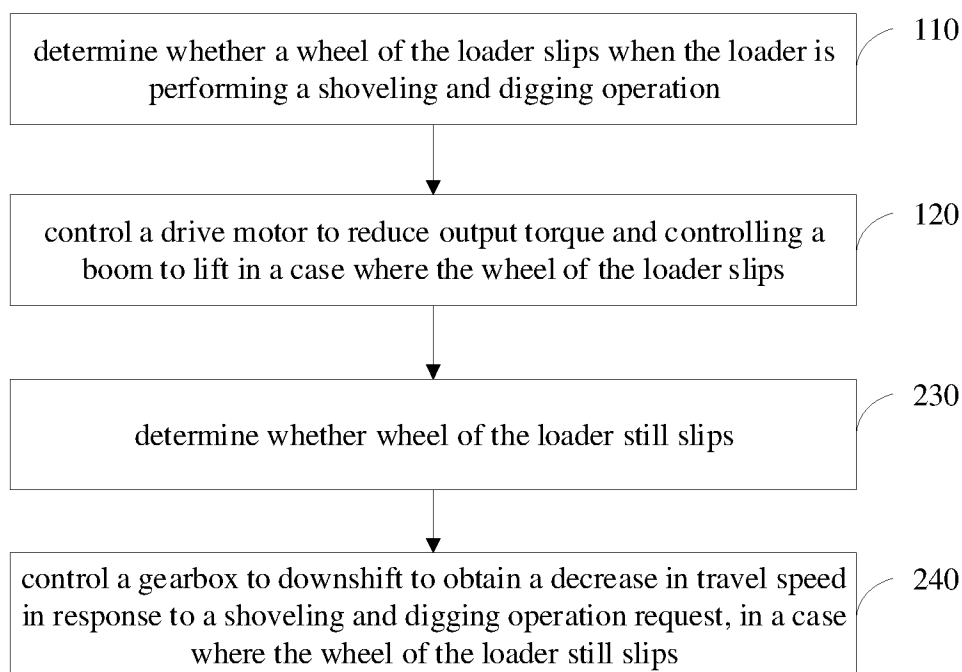


FIG. 2

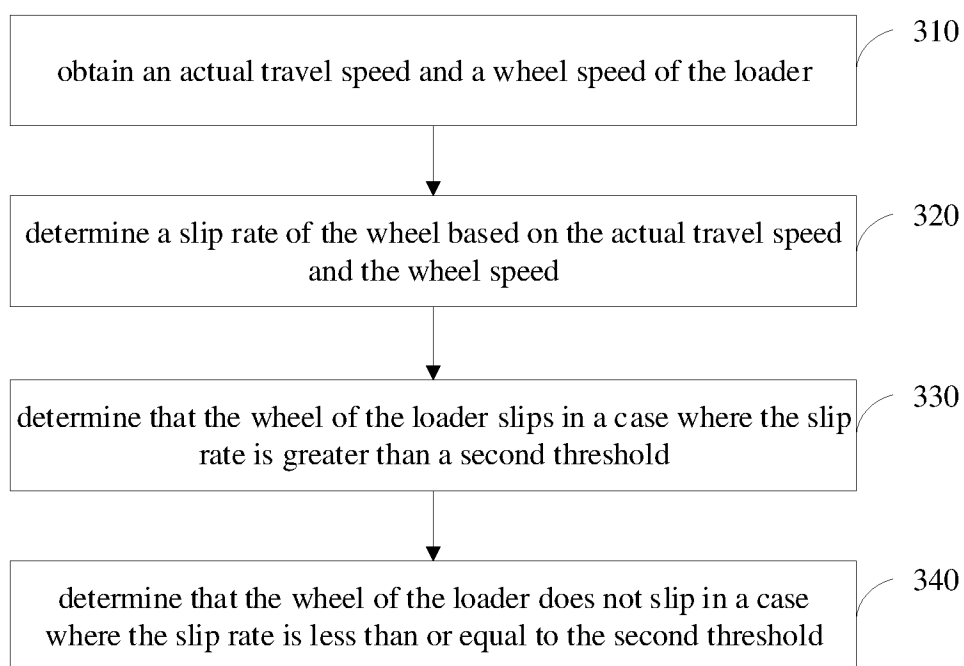


FIG. 3

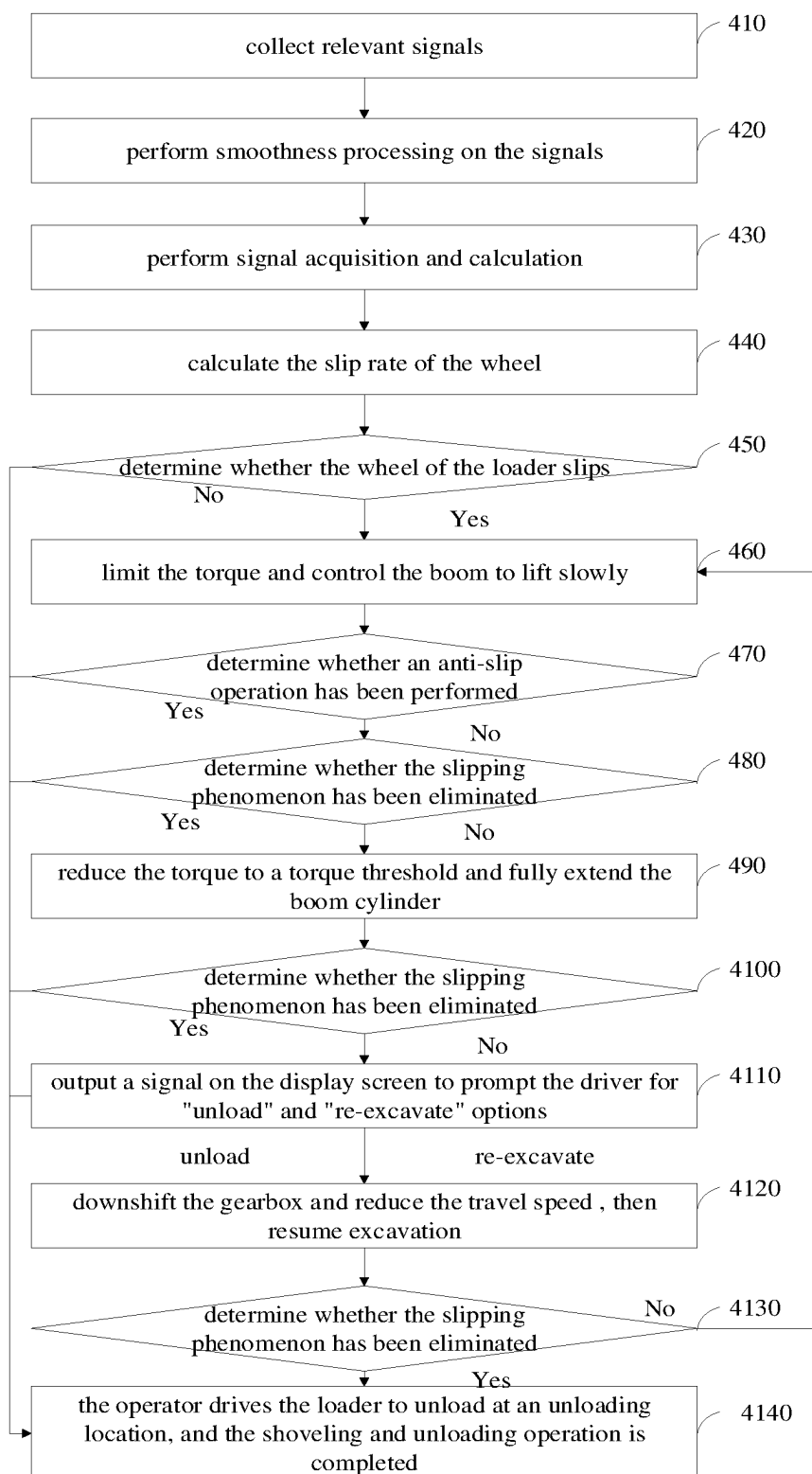


FIG. 4

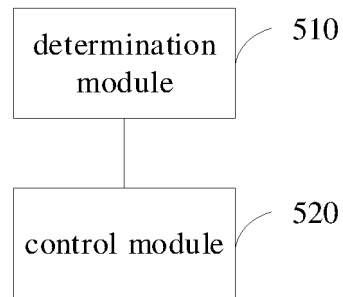


FIG. 5

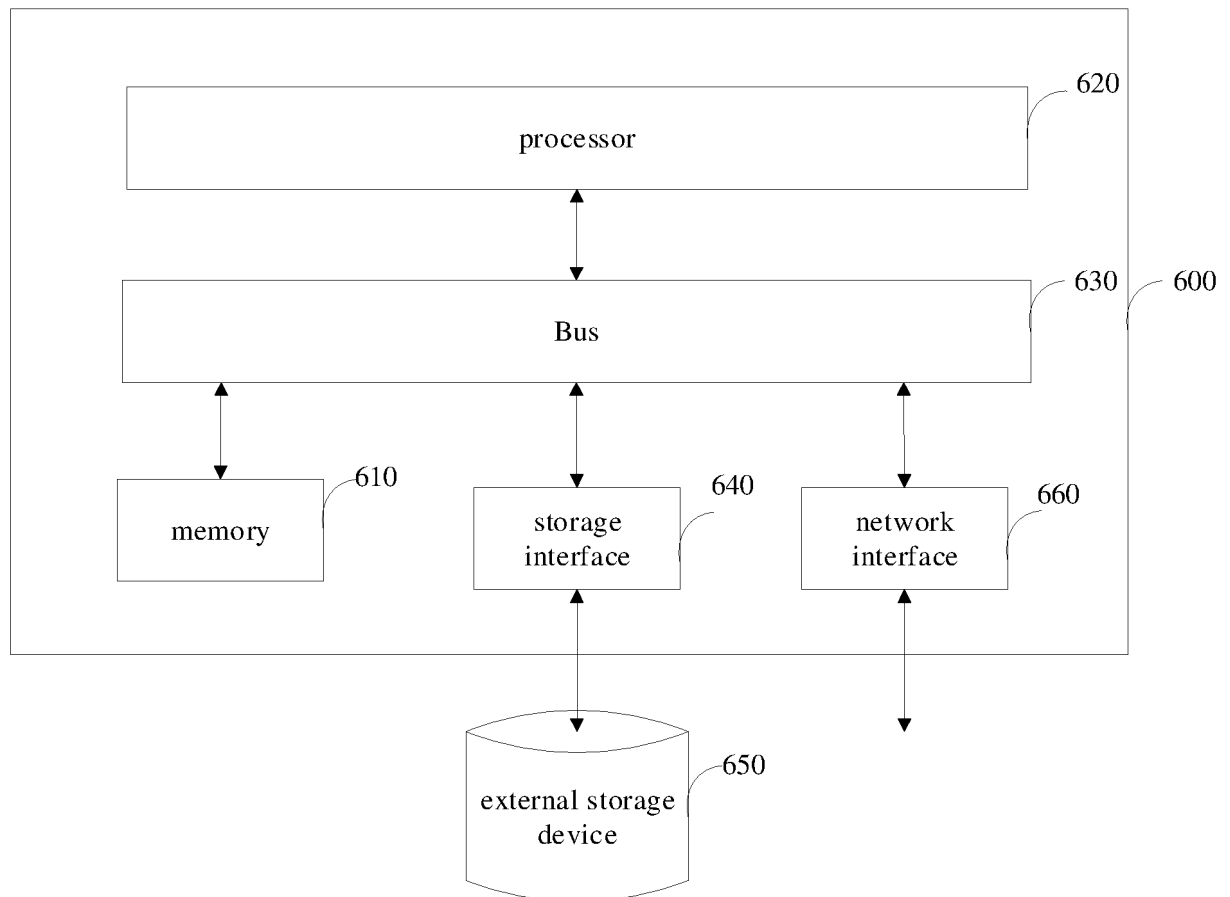


FIG. 6

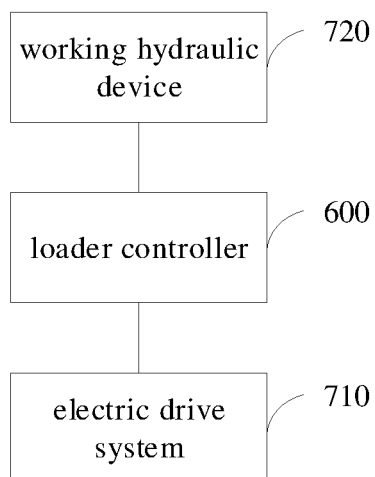


FIG. 7

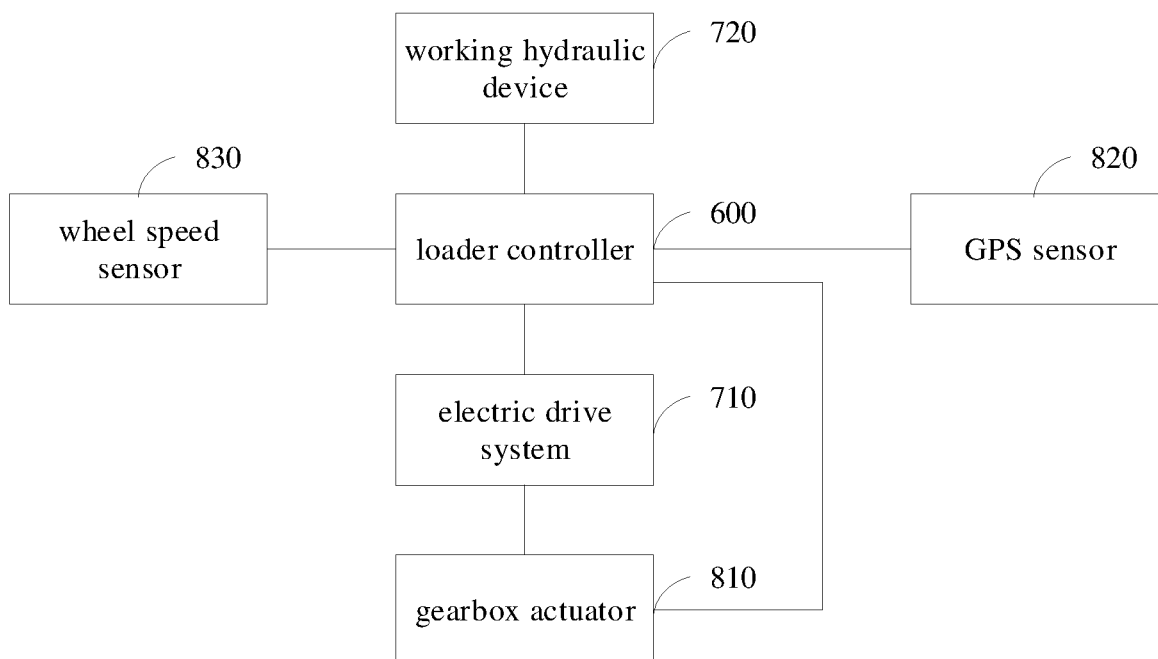


FIG.8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/070105

A. CLASSIFICATION OF SUBJECT MATTER

E02F9/20(2006.01)i; E02F9/22(2006.01)i; E02F3/42(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: E02F9; E02F3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT; ENTXTC; CJFD; ENTXT; VEN: 装载机, 电动, 打滑, 扭矩, 降低, 动臂, loader, loading, skid+, slipping, trackslip, slid+, torque, torsion+, debas+, fall+, reced+, reduc+, depress+, low+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 117248588 A (JIANGSU XCMG GUOZHONG LABORATORY TECHNOLOGY CO., LTD.) 19 December 2023 (2023-12-19) claims 1-15, and description, paragraphs 127-130	1-16
Y	CN 113910921 A (BRETON TECHNOLOGY CO., LTD.) 11 January 2022 (2022-01-11) description, paragraphs 23-47	1-16
Y	CN 113818505 A (XUZHOU CONSTRUCTION MACHINERY GROUP CO., LTD., SCIENCE AND TECHNOLOGY BRANCH) 21 December 2021 (2021-12-21) description, paragraphs 20-33	1-16
A	CN 115571131 A (SAUTER TRANSMISSION EQUIPMENT CO., LTD.) 06 January 2023 (2023-01-06) entire document	1-16
A	CN 113737884 A (WEICHAI POWER CO., LTD.) 03 December 2021 (2021-12-03) entire document	1-16
A	US 2023235535 A1 (DEERE & COMPANY) 27 July 2023 (2023-07-27) entire document	1-16

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

14 June 2024

Date of mailing of the international search report

18 June 2024

Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/
CN)China No. 6, Xitucheng Road, Jimenqiao, Haidian District,
Beijing 100088

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/070105

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2019112339 A1 (DOOSAN INFRACORE CO., LTD.) 13 June 2019 (2019-06-13) entire document	1-16
A	US 2019337386 A1 (CATERPILLAR, INC.) 07 November 2019 (2019-11-07) entire document	1-16
A	US 2022349155 A1 (CATERPILLAR, INC.) 03 November 2022 (2022-11-03) entire document	1-16

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2024/070105

5

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	117248588	A	19 December 2023	None			
CN	113910921	A	11 January 2022	None			
CN	113818505	A	21 December 2021	None			
CN	115571131	A	06 January 2023	None			
CN	113737884	A	03 December 2021	None			
US	2023235535	A1	27 July 2023	DE	102022210721	A1	27 July 2023
WO	2019112339	A1	13 June 2019	EP	3722514	A1	14 October 2020
				EP	3722514	A4	27 October 2021
				KR	20190067417	A	17 June 2019
				KR	102473513	B1	02 December 2022
US	2019337386	A1	07 November 2019	US	11046180	B2	29 June 2021
				AU	2019202430	A1	21 November 2019
				DE	102019110750	A1	07 November 2019
US	2022349155	A1	03 November 2022	WO	2022231731	A1	03 November 2022
				EP	4330100	A1	06 March 2024

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 202311467067 [0001]