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(54) **TRACTION CONTROL DURING LOADING OPERATIONS OF A MINING MACHINE**

ANTRIEBSREGELUNG BEI LADEVORGÄNGEN EINER BERGBAUMASCHINE

RÉGLAGE DE LA TRACTION PENDANT LES OPÉRATIONS DE CHARGEMENT D'UNE MACHINE MINIÈRE

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(73) Proprietor: **Sandvik Mining and Construction Oy**
**33330 Tampere (FI)**

(72) Inventors:
- **VERHO, Samuli**
  **33311 Tampere (FI)**
- **VATANEN, Harri**
  **33311 Tampere (FI)**

(74) Representative: **Sandvik**
**Sandvik Mining and Construction Oy**
**Patent Department**
**PL 100**
**33311 Tampere (FI)**

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## Description

FIELD

**[0001]** The present invention relates to loading work machines, and in particular to traction control during loading operations by such vehicles.

BACKGROUND

**[0002]** Mining or construction excavation worksites, such as hard rock or soft rock mines, may comprise areas for automated operation of mobile work machines, which may also be referred to as mine vehicles. Such work machine may be an unmanned, e.g. remotely controlled from a control room, or a manned mine vehicle, i.e. operated by an operator in a cabin of the mobile vehicle. Work machines may be configured to perform at least some of tasks autonomously. An automated work machine operating in an automatic mode may operate independently without external control but may be taken under external control at certain operation areas or conditions, such as during states of emergencies.

**[0003]** Loading equipment may be used to load and transport excavated material, such as ore, rocks or sand from one place to another, for example after excavation from an underground mine loading position to out of the mine or to a conveyor transport equipment or a sport reserved for unloading the material. Due to the dynamic and unpredictable nature if bucket-rock interactions, it is very challenging to develop automated bucket filling that would work efficiently at various loading conditions. A loading controller needs to manage not only the motion of excavation arms, such as boom and bucket positions, but also penetration rate based on motion of loading equipment platform. For example, the forces that act on a bucket as it is actuated to penetrate a rock pile may vary significantly depending on the properties of rock media in the pile, pile geometry, and distribution of particle sizes and geometry. One particular issue is wheel slipping during loading, causing wear of tires and also wear of the loading position.

**[0004]** Patent publication EP3207187 discloses a method for controlling automated bucket loading. A bucket control profile is selected from a set of bucket control profiles, the profiles comprising indications for positions of the boom of the work machine as a function of a distance travelled by the work machine with reference to a reference location. A wheel slippage detection system may be included and a bucket control profile may be changed in response to detecting slippage.

SUMMARY

**[0005]** The invention is defined by the features of the independent claims. Some specific embodiments are defined in the dependent claims.

**[0006]** According to a first aspect, there is provided an apparatus as defined in independent claim 1.

**[0007]** The means may comprise at least one processor, and at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processor, cause the performance of the apparatus.

**[0008]** According to a second aspect, there is provided a method for traction control, comprising: detecting a work machine comprising an electric driveline, a boom, and a bucket connected to the boom to enter a bucket loading mode, and initiating a bucket loading specific traction control procedure in response to detecting the work machine to enter the bucket loading mode, the traction control procedure comprising:

- receiving driveline information of at least one component of the electric driveline, wherein the driveline information is information generated on the basis of signals from the at least one component of the electric driveline, and wherein the at least one component of the electric driveline is an inverter unit, an electric motor, a gearbox, or a transmission mechanism;
- detecting a wheel slip condition during the bucket loading mode on the basis of the driveline information and at least one slip condition threshold value preconfigured for the bucket loading mode,
- defining a bucket loading specific traction control parameter set in response to the detected slip condition, and
- controlling speed and torque of the electric driveline on the basis of the defined traction control parameter set, whereby no physical sensors are required for the bucket loading specific traction control procedure.

**[0009]** According to a third aspect, there is provided an apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform the method or an embodiment of the method.

**[0010]** According to a fourth aspect, there is provided a computer program, a computer program product or (a non-tangible) computer-readable medium comprising computer program code for, when executed in a data processing apparatus, to cause the apparatus to perform the method or an embodiment thereof.

**[0011]** According to an embodiment of any of the aspects, the bucket loading mode is an automatic bucket loading mode in which control actions and associated control parameters to move the bucket, the boom and body of the work machine (during the bucket loading mode and procedure) are performed automatically, controlled by a control unit of the work machine. The automatic bucket loading may be adaptive, adjusting based on sensor and/or other work machine state information,

in an embodiment based on driveline information. In an alternative embodiment, the present (automatically activating) bucket loading specific traction control assists an operator of the work machine at least partially controlling bucket loading in the bucket loading mode, which may thus be referred to as at least partially manual bucket loading mode.

**[0012]** According to an embodiment of any of the aspects, the work machine comprises sensor means for determining speed of front wheels of work machine, the speed difference of the front wheels is determined based on signals from the sensor means, and the slip condition is detected in response to the speed difference exceeding a traction control threshold value preconfigured for the bucket loading mode.

**[0013]** According to an embodiment of any of the aspects, a parameter in the set is applied for a predefined period of time identified by the set.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]**

FIGURE 1 illustrates an example of a work machine equipped with a bucket;

FIGURE 2 illustrates a method according to at least some embodiments;

FIGURE 3 illustrates a control arrangement for a work machine;

FIGURE 4 illustrates examples of applying bucket loading specific traction control procedure; and

FIGURE 5 illustrates an example apparatus capable of supporting at least some embodiments.

## EMBODIMENTS

**[0015]** The presently disclosed embodiments are applicable, in particular, to various remotely operable loading work machines used in mining industry, construction sites etc., suitable for loading, transporting and unloading excavated material or other bulk material. Particular examples of such work machines include loading equipment or loaders comprising a bucket attached to a boom. The excavated material may, for example, be rocks excavated in a surface or underground operating area. In this context, the term "rock" is to be understood broadly to cover also a boulder, rock material, crust and other relatively hard material.

**[0016]** Fig. 1 shows an example of a work machine 10 comprising a (mobile) carrier 12, one or more booms 14 and a bucket 16 attached in a pivotable or otherwise movable manner to the one or more booms 14. For example, the bucket 16 may be coupled to two booms 14. The attachment may comprise at least one pivot 22, and the bucket 16 may be turned with respect to the pivot(s). The work machine 10 may be an articulated vehicle comprising two sections connected by a joint 32. The work machine may be a load and haul (LHD) device, or a device mainly intended for loading.

**[0017]** The work machine 10 further comprises a first actuator 18 for moving the boom 14 upwards and downwards, and a second actuator 20 for turning the bucket 16 in respect to the pivot 22. The actuators 18, 20 may be hydraulically and/or electrically operable actuators, or operable by some other source of energy. It should also be noted that Figure 1 is simplified and e.g. the first actuator 18 and/or the second actuator 20 may in practise comprise more than one actuator. For example, a lever arm arrangement may be applied for connecting a cylinder to the bucket 16.

**[0018]** The work machine 10 typically comprises a pump system 24 for generating hydraulic pressure for operating various parts of the machine, such as lifting the boom 14, turning the bucket, 16 etc. The work machine 10 may comprise one or more other sources of energy, such as an accumulator, a hydrogen container, a fuel tank, etc. The work machine 10 may comprise at least one motor 26, such as an electric motor or both an electric and a combustion motor. Power from the motor 26 may be provided by a crank shaft (not shown) to front and/or rear wheels 28 either directly or via a gear box (not shown).

**[0019]** The work machine 10 comprises at least one control unit 30, which may comprise one or more processors and memory, configured to control at least some functions and/or actuators of the work machine. In some embodiments, the control unit 30 is configured to control at least operations during bucket loading, and there may be one or more other control units in the work machine for controlling other operations. It is to be appreciated that the control unit 30 may be configured to perform at least some of the below illustrated features, or a plurality of control units or controllers may be applied to perform these features. There may be further operations modules or functions performed by the control unit(s), e.g. an automatic bucket loading function, positioning function, autonomous driving control function, and/or an obstacle detection function.

**[0020]** The work machine 10 may be an automated work machine, which in its autonomous operating mode may operate/drive independently without requiring continuous user control but which may be taken under external control during states of emergencies, for example.

**[0021]** The work machine 10 may comprise a wireless data transfer unit 34, by which the control unit 30 may establish a data transmission connection to another (second) control system 40 external to the work machine 10 by utilising a wireless connection provided by a base station or access node 42. The data transfer unit 34 may thus be connected to a communications system of the worksite, such as a wireless access system comprising a wireless local area network (WLAN) and/or a cellular

communications network (e.g. a 4G, 5G or another generation cellular network).

**[0022]** The system 40 may comprise or be connected to a further network(s) and/or data processing system(s), such a worksite management system, a cloud service, a data analytics device/system, an intermediate communications network, such as the internet, etc. The system may comprise or be connected to further device(s) or control unit(s), such as a handheld user unit, a vehicle unit, a worksite management device/system, a remote control and/or monitoring device/system, data analytics device/system, sensor system/device, etc.

**[0023]** For example, a server of the system 40 may be configured to manage at least some operations at the worksite, such as provide a UI for an operator to remotely monitor and, when needed, control automatic operation operations of the work machines and/or assign work tasks for a fleet of vehicles and update and/or monitor task performance and status. Thus, the work machine 10 may be unmanned, the user interface may be remote from the work machine, and the work machine may be remotely monitored or controlled by an operator in proximity to the work machine (e.g. in the tunnel), or in a control room at the worksite or even long distance away from the worksite via communications network(s). However, it is to be noted that the below described features may be applied also in manually-operated machines to assist bucket filling.

**[0024]** The work machine 10 may comprise a positioning system or unit. At surface-operated work machines, it may be possible to use satellite-based navigation, such as the GPS system, for determining the location and orientation of the mining vehicle with sufficient accuracy. At underground-operating work machines, instead of satellite based positioning information, positioning based on dead-reckoning and/or scanning tunnel surfaces may be used.

**[0025]** The work machine 10 may comprise one or more scanning units, or scanners 36, configured to perform scanning of the environment of the work machine. In an embodiment, the scanner 36 may be a 2D or 3D scanner configured to monitor tunnel walls. The control unit 30 may compare operational scanned tunnel profile data to reference profile data stored in an environment model and position the work machine on the basis of finding a match in the environment model to position the work machine and/or correct positioning by dead-reckoning. In some embodiments, the scanning results are applied to detect position and orientation of the work machine and one or more further elements thereof, such as the scanner 36 or the bucket 16.

**[0026]** A driving plan, or a route plan, may define a route to be driven by the work machine 10 and may be used as an input for automatic control of the work machine. The plan may define a start point, an end point, and a set of route points for the automatic drive. The driving plan may comprise information of loading area or point and may comprise data for controlling loading of the bucket 16. Bucket loading mode may be initiated in response to the work machine entering a position or route point of loading area in the driving plane. The driving plan may be sent via a wired or wireless connection to, or otherwise loaded to the work machine, to a memory of the work machine for access by the control unit 30.

**[0027]** During bucket loading the work machine 10 is driven near a stack or pile 50 of excavated material such as ore, rocks or sand. The bucket 16 and also the boom 14 may be lowered down, such that the bucket is on the surface of the ground or near it. The work machine may be driven forward so that the bucket contacts the pile. Bucket loading comprises many stages and actions and it is a difficult task especially for an operator with less experience. If the work machine stops due to too high resistance of the stack of material, the bucket may be lifted upwards, which may enable driving the work machine 10 a bit further, etc.

**[0028]** The bucket loading procedure by the work machine 10 may be automated, i.e. the machine may autonomously perform a sequence of appropriate movements of the work machine body, the boom 14 and the bucket 16, controlled by the controller unit 30 to fill the bucket 16 and complete the loading by entering a boom position appropriate for leaving the pile 50 and hauling the load to an unloading location. There is generally a need to improve existing bucket filling solutions which do not always work very well in changing rock pile conditions, e.g. where rock dimensions vary considerably. This results only partially filled buckets.

**[0029]** One particular issue during loading is slipping of wheels, causing unnecessary wear and tear of wheels and also affecting to loading of the bucket. An anti-slip system used for driving the work machine is not optimal for bucket loading and may reduce traction too much. It is difficult to have optimally operating traction control for varying loading conditions particularly for diesel drivelines. Speed and torque are not so well and fast controlled. When traction control is activated, it may restrict tractive effort force of diesel driveline non-optimally. In the current systems wheel speed sensors are typically included for all driving wheels to detect slipping. System becomes quite complicated and needs to be well-tuned to operate appropriately in various loading situations. In order to improve traction system, a specific brake valve for each wheel could be installed. Then the traction control could be smoother, but system would be even further complicated.

**[0030]** There is now provided an improved solution for bucket loading, with a bucket loading specific traction control procedure, enabling to simplify the system and further improve bucket filling efficiency in varying conditions.

**[0031]** Figure 2 illustrates a method according to some embodiments. The method may be performed by a work machine and a controlling apparatus thereof, such as the work machine 10, and by the control unit 30 thereof.

**[0032]** The method for controlling traction of work ma-

chine during loading may comprise detecting 200 a work machine comprising an electric driveline, a boom, and a bucket connected to the boom to enter a bucket loading mode. A bucket loading specific traction control procedure is initiated 210 in response to detecting the work machine to enter the bucket loading mode. The traction control procedure comprises:

- receiving 220 driveline information of at least one component of the electric driveline,
- detecting 230 a wheel slip condition during the bucket loading mode on the basis of the driveline information and at least one slip condition threshold value preconfigured for the bucket loading mode,
- defining 240 a bucket loading specific traction control parameter set in response to the detected slip condition, and
- controlling 250 speed and torque of the electric driveline on the basis of the defined traction control parameter set.

**[0033]** The bucket loading specific traction control procedure (which may also be referred e.g. as anti-slip control procedure) comprises control action(s) for reducing slipping, configured for and applied during bucket loading. Detecting the wheel slip condition may refer to identifying, based on at least the driveline information, that at least one wheel of the work machine is likely slipping. The bucket loading specific traction control parameter set refers to a set of control parameters defined for and applied during bucket loading. The parameter set may be defined 240 on the basis of the driveline information, which may be substantially continuously received (thus also after block 230). During the traction control procedure, on the basis of the received driveline information, traction control may be repetitively switched on and off (in response to detecting termination of the slip condition). During the slip condition, level of applied traction control affecting the speed and torque may be adapted based on newly received driveline information. Also further information may be applied in block 230 and/or 240, such as sensor information.

**[0034]** The driveline information refers generally to information indicative of status or parameter of a driveline (may also be referred to as powerline) component or system. Electric driveline components of a work machine typically comprise an inverter unit, an electric motor, a gearbox, and a transmission mechanism. However, in some embodiments, the driveline information comprises (only) information indicative of current status of the motor, or a unit controlling the motor. The driveline information may be received from a driveline component or a control system or unit thereof. According to the invention the driveline information is received from an inverter unit or another type of (drive control) unit driving or controlling the electric motor. The driveline information is generated on the basis of signals from the driveline component(s). In some embodiments, the driveline information is indicative of driveline rotational speed and/or torque status. The slip condition threshold value(s) may comprise driveline threshold value(s), such as threshold value on motor rotational speed or RPM

**[0035]** It is also to be noted that the speed controlled in block 250 is to be understood broadly to speed control of the electric driveline, such as instructing the inverter unit with information affecting ground speed or motor speed.

**[0036]** When the bucket loading specific traction control parameter sets are preconfigured in a memory of the work machine 10, such as memory accessible by the control unit 30, the work machine may in block 240 select one parameter set amongst the stored parameter sets based at least on the received driveline information. The work machine may also be configured to dynamically generate some or all of the values in the parameter set, based on preconfigured control logic. In a simple example, the control unit 30 is configured to define new target or limit speed and/or torque value, which is reduced by predetermined amount from current target or limit value, e.g. by 40%.

**[0037]** Temporal relationship between at least some of the plurality of control parameters in the bucket loading specific traction control parameter set may be defined. Such temporal relationship information, such as timing information for parameters in the set, may be stored as part of the parameter set.

**[0038]** The bucket loading specific traction control parameter set may be a sequence of control parameters. Timing of at least some of parameters may be defined in the set. A control parameter may define a target value for a controlled entity, and control action may be initiated in block 250 to approach the target value. The set of parameters may comprise a plurality of subsequent values for a given parameters. Different values may have different durations, i.e. time periods during which they are applied. There may be another criterion than time elapsed or time threshold for changing the value, some examples being illustrated below.

**[0039]** Figure 3 illustrates an arrangement and elements of the work machine, such as the work machine 10, for controlling the work machine by applying the method of Figure 2 and at least some embodiments thereof. In this example, driveline 300 of the work machine comprises an electric motor 304 driven by an inverter unit (INU) 302. The INU 302 comprises an inverter, which at least in some instances may also be referred to as frequency converter, alternative current (AC) drive, variable speed drive (VSD), or variable frequency drives (VFD), controlling the voltage and frequency of power supplied to an AC motor to control the torque and rotation speed of the motor 304.

**[0040]** Wheels 28, such as front wheels and rear wheels of the work machine 10 are rotated by a transmission mechanism 308. The transmission mechanism 308 is rotated by a gear box (or drop) assembly 306. The gear box is driven by the electric motor 304. The INU 302

is powered by electric energy from an electrical supply of the work machine (not shown). However, it is to be noted that the driveline may also comprise or be connected also another type of energy source. In an example embodiment, a combustion motor, e.g. a diesel generator is applied, and the generated energy is used directly by the electric driveline or stored in a battery. Thus, the work machine and the driveline may be hybrid.

**[0041]** A control system or unit 310, such as the control unit 30, may be configured to perform the method of Figure 2 and receive 220 information from the driveline 300. The control unit 310 may comprise one or more computing units/processors executing computer program code stored in memory. The control unit may be connected to one or more other control units of a control system of the work machine, in some embodiments by a controller area network (CAN) bus. The control unit 310 may thus obtain the driveline information (e.g. provided to the bus by the INU 302) from the bus system.

**[0042]** The driveline information (received in block 220) may indicate current electric motor 304 speed and/or torque. In some embodiments, also further (traction control affecting) information, which may assist to identify wheel slipping and/or in block 240, is received 220 from the INU 302. Such traction control information may be indicative of one or more of electric motor power, electric motor current, electric motor voltage, electric supply side voltage, electric supply side current, and inverter internal limitation information. In a further example, the control unit 30, 310 determines difference between currently instructed motor speed and current actual motor speed (based on the received driveline information), and applies the difference in block 230 and/or 240 (there may be one or more difference threshold values applied).

**[0043]** The INU 302 is controlled by the control unit 310 on the basis of parameter(s) in the defined bucket loading specific traction control parameter set to control the driveline 300 of the work machine. The control unit 310 may be configured to transmit control signals in accordance with the defined set of control parameters to the INU 302 to control driveline rotational speed and/or torque.

**[0044]** The bucket loading specific traction control parameter set, defined in block 240, and which may be controlled by the control unit 310 as control signals to the driveline 300, may be indicative at least one of electric motor power request and/or limitation, electric motor torque request and/or limitation, speed request and/or limitation, and inverter internal limitation information.

**[0045]** The control unit 310 may in some embodiments be directly or indirectly connected also to further elements of the driveline, such as the motor 304 or a further controller thereof, or a sensor in the driveline. For example, the RPM (revolutions per minute) of the front wheel(s) can be measured by RPM sensor(s). The control unit 310 may obtain the RPM information from the driveline and process it by an algorithm to detect slippage or spin of the wheels (in case there is a differential lock). The algorithm may be configured to maintain the RPM within a predetermined range. The driveline RPM can be readily obtained and the wheel RPM calculated therefrom.

**[0046]** The control unit 310 may be connected to an actuator control unit or (sub)system 320, which may be connected to boom actuator (BoA) 322 and bucket actuator (BuA) 324. The control unit 310 may issue control signals during the bucket loading mode, according to defined bucket and/or boom control parameters, which in an embodiment may be adaptively and dynamically defined on the basis of driveline information, to the actuator control system 320, which controls the BoA 322 and BuA 324 to accordingly control the boom 14 and the bucket 16. It is to be noted that the boom and the bucket may have separate actuator controls, which may be directly connected to the control unit 310. Actuator control (sub)system may comprise or be connected to hydraulic circuits having lift and tilt actuator control valves for controlling the rate at which pressurized hydraulic fluid flows to respective lift and tilt hydraulic actuators in proportion to control signals.

**[0047]** A user interface (UI) 330 may be connected to the control unit 310, comprising e.g. a joystick, a touch screen, or other input means by which an input signal from a user may be provided to the control unit for affecting e.g. the traction control and loading operations.

**[0048]** The control unit 310 may be connected to further units in the work machine, such as further sensors or sensor systems 340 and 350. Some examples of such sensors include boom or bucket limit sensors, boom or bucket position detection sensors and hydraulic pressure sensors.

**[0049]** Example sensor 350 may be a wheel rotation sensor. The control unit 310 may receive wheel rotation information. The control unit may detect 230 the slip condition during the bucket loading mode on the basis of the received wheel rotation information and a predefined wheel rotation or traction control threshold value preconfigured for the bucket loading mode.

**[0050]** In an example embodiment, sensor means 350 are arranged at right and left front wheels 28 for determining speed of the front wheels. The control unit 310 may determine speed difference of the front wheels based on signals from the sensor means and detect 230 the slip condition in response to the speed difference exceeding a traction control threshold value preconfigured for the bucket loading mode.

**[0051]** In some embodiments, the wheel slip condition is detected 230 and/or traction control parameter set is defined 240 or changed on the basis of information from the sensor means 350, indicative of wheel slip during the bucket loading mode. However, it is to be appreciated that the wheel slip condition may be detected and bucket loading specific traction control performed (and associated parameter set selected) without such sensor information and sensors. The wheel rotation sensor and associated information may be used as an additional input to the method.

**[0052]** The work machine 10 of Figure 1 and the ar-

rangement of Figure 3 are disclosed herein only as examples where the embodiments disclosed herein may be implemented. The embodiments are applicable to various other types and configurations of work machines and control units.

**[0053]** There may be one or more triggering conditions or events in block 200 and detecting the work machine to enter the bucket loading mode. In some example embodiments, block 200 may comprise detecting at least one of:

- the work machine to enter a predefined bucket loading entry position,
- the bucket at a position associated with start of bucket loading,
- the boom at a position associated with the start of bucket loading,
- an input from an operator to initiate bucket loading,
- a joystick of the work machine at a position with the start of bucket loading, and
- other work machine control system data associated with bucket loading indicating entering or a need to enter the bucket loading mode.

**[0054]** It is to be noted that the position may refer to a position area, e.g. current position of the boom 14 is in a lower portion of its area of mobility. The predefined bucket loading entry position may be a route point associated with loading area, or other type of indicator in position information, such as a loading area indicator. The bucket loading mode may be automatically entered in response to detecting that the current position of the work machine 10 matches with the predefined position. The associated bucket or boom position may be a predetermined angle or angle area. In another example embodiment, the associated bucket or boom position is detected in response to receiving a signal from a limit switch, whereby position sensor may be avoided. It is to be noted that a combination of conditions may be required; for example, all the first three conditions of the above list need to be met.

**[0055]** Blocks 220 to 250 may be repeated during the bucket loading mode and the associated traction control procedure. The work machine 10, and the control unit 30, 310 thereof (which may also apply to the other embodiments below referring to the work machine), may define, on the basis of the driveline information and one or more threshold conditions, if redefinition or change of applied traction control parameter set or one or more control parameters thereof is to be triggered.

**[0056]** The bucket loading specific traction control procedure may thus dynamically adapt to the changing conditions detected based on the driveline information. The work machine 10 may determine, during the bucket loading mode and the traction control procedure, if a change condition for changing the defined traction control parameter set or at least one parameter in the defined traction control parameter set is met. In an example embodiment, a need to adapt one or more parameters in the defined set is detected, and such parameters may be dynamically adapted during application of the set. In response to the change condition being met, applied traction control parameter set or at least one parameter in the defined traction control parameter set is (re)defined and changed. The change condition may comprise at least one driveline information threshold value, wheel slip condition threshold value, and/or a temporal threshold value, for example. Examples of driveline information threshold values, which may also be applied as the slip condition threshold value(s) in block 230 and as slip condition termination threshold value(s), include at least one threshold value on driveline or motor rotational speed or RPM, a threshold value on torque and/or power.

**[0057]** The work machine 10 may thus continue to monitor at least driveline information during and after the controlling 250 on the basis of the defined traction control parameter set. In response to further detecting a slip condition, one or more further control actions and associated parameters may be defined and applied. In an example embodiment, an updated traction control parameter set may be defined for controlling the speed and torque of the electric driveline to further reduce wheel slipping. Alternatively or additionally, boom and/or bucket control parameter to (further) reduce the wheel slipping may be defined and applied.

**[0058]** Time of applying the defined traction control parameter set or some parameters thereof may be monitored. Change of the control parameter set or at least some parameters thereof to control speed and torque of the electric driveline may be controlled in response to the time of applying the defined set exceeding a threshold value. This enables to ensure that a control parameter set (and associated traction control action) is not applied unnecessarily long. In an example embodiment, a parameter in the control parameter set is applied for a predefined period of time identified by the set, i.e. some parameters of the set may be applied only for part of the loading action and application time of the parameter set.

**[0059]** The system comprising the present bucket loading specific traction control procedure may provide an interface for the user to tune the procedure, e.g. via the UI 330. There may be several parameters affecting sensitivity of the procedure. Even though the present traction control procedure enables to adapt very well to the current slipping conditions based on the driveline information, it may be desirable to be able to control the sensitivity of the procedure, e.g. it may be desirable to allow certain amount of wheel slipping in at least some bucket loading events or stages, or prevent wheel slipping entirely to minimize tear. The interface may be configured such that only one (or two/three) sensitivity tuning parameters (or groups of parameters) or profiles are available for control via the UI, enabling simple manual tuning modification by operator during use of the machine. In a further embodiment, the present traction control procedure and parameters thereof may be controlled

or configured automatically on the basis of the current location of the work machine. This enables further automatic tuning for varying bucket filling circumstances at different spots of a mine, for example.

**[0060]** The traction control procedure may be terminated in response to detecting termination of the bucket loading mode. For example, the bucket loading mode may be terminated in response to loading completion or finish stage or action being completed or entered (e.g. lifting and shaking boom), the boom entering a driving position, a user input, information indicative of bucket being full enough (e.g. based on hydraulic pressure), the work machine leaving the bucket loading position or area, etc. In a further example, such termination condition is determined in response to receiving a signal from a bucket limit switch.

**[0061]** The present features and adaptive bucket loading specific traction control procedure facilitate to provide well-functioning traction control for automatized bucket loading, supporting effective bucket filling in varying loading conditions. The bucket loading specific traction control is designed and optimized for the very specific bucket loading event, differing substantially from normal driving traction control requirements. The present traction control procedure does not have to be configured to support a large number of different normal driving situations, speeds, or conditions. Wheel slipping, and associated wearing of tires, may be reduced, but at the same time appropriate force ensured for bucket filling.

**[0062]** The driveline information and the electric driveline may be considered as a sensor enabling to substantial improve the optimized operation of traction operations for bucket loading, since the driveline information reflects loading situation very well. Based on algorithm suitably configured to apply the driveline information, it is possible to have exact knowledge of what is currently happening in the loading process and instantly define and apply appropriate set of control parameters, enabling to have maximum force available against muck pile under current slipping conditions. Since physical sensors, such as ground radar, wheel rotation sensor(s) or scanners, are not required for traction control, traction control arrangement may be substantially simplified. Since there are less physical devices susceptible to break or malfunction in the demanding conditions, robustnes is improved. The system has been tested with an LHD and shown to work smoothly and effectively.

**[0063]** When combined with automatic driving and unloading, worksite operations of a LHD can be automated completely with the automatic bucket loading system comprising the bucket loading specific traction control procedure. The presently disclosed automatic adaptive traction control procedure may also well be applied in connection with manual operation, and assist in the most difficult phase of LHD operation particularly for less-experienced and remote operators.

**[0064]** The bucket loading mode may be an automatic bucket loading mode in which control actions and associated control parameters to move the bucket 16, the boom 14, and body of the work machine 10 during the bucket loading mode to carry out bucket loading procedure are performed automatically, controlled by the control unit 30, 310 of the work machine. The presently disclosed bucket loading specific traction control procedure may be comprised in or applied for an automatic adaptive bucket loading based on adaptive control parameter set adjustment based on driveline information, enabling to further improve bucket filling efficiency in varying conditions. Position of the boom, position of the bucket, and speed of the work machine may be controlled on the basis of a set of control parameters defined based on received driveline information (indicative e.g. of rotational speed and/or torque status). Thus, no pre-taught or otherwise defined profiles of bucket and/or boom (indicative of positions of the bucket/boom in relation to a distance travelled by the work machine) are required. Such dynamically adapting loading procedure may be completely provided without a predefined profile and associated boom/bucket position and distance measurements. This simplifies the system and enables to avoid problems e.g. due to malfunctioning position sensors.

**[0065]** Figure 4 illustrates examples and associated information when applying the bucket loading specific traction control procedure, which may be performed by the work machine 30 and the control unit 30, 310. There are five graphs with differing information signals, aligned in time (x-axis, starting from 0). The first (from up to down) graph illustrates whether traction control is activated (1.0) or not (0.0). Traction control activation may here refer to entering block 240 in response to detecting a wheel slip condition, in the present example on the basis wheel speed difference and/or motor measurements.

**[0066]** The second graph illustrates left wheel speed (line with dots) and right wheel speed (solid line). The third graph illustrates current front wheel speed difference (solid line) and dynamically adapted traction control activation limit for speed difference (line with dots; invariable in this example). The fourth graph illustrates motor speed (solid line) and motor speed command (line with dots). The fifth graph illustrates motor torque (solid line) and dynamically adapted motor torque limitation (line with dots).

**[0067]** For example, around time instant 0.35, wheel slip condition is detected based on driveline information. Motor speed increases 600 (may meet a threshold value in relation to speed command for traction control). Based on this and other driveline information (such as motor power information, control algorithm detects slip condition and instantly activates 602 traction control. This illustrated situation may be a four wheel slip condition.

**[0068]** In another example, after time instant 0.6, right wheel starts to slip and its speed increases 604, and the wheel speed difference meets 606 traction control activation limit. Also motor speed increases 608 above current motor speed command. Traction control is activated 610, controlling motor speed command 612 with reduced

motor speed and reduced motor torque (limit) 614. After time instant 0.8, the speed difference reduces, at 616 under the TC activation limit. Also the motor speed goes down. The traction control is switched off, and motor speed and torque are increased. However, the speed of left wheel increases 618, and TC is again activated, controlling reduced motor speed 620 and torque 622. Fig. 4 also illustrates how the speed command and torque limit may dynamically adjust during the active traction control to quickly and softly end the slipping.

**[0069]** The work machine 10 and the control unit thereof 30, 310 may record history information of used traction control parameter sets used during bucket loading modes. The traction control parameter set may be defined in block 240 further on the basis of the history information. The automatic adaptive loading system may be configured to learn on the basis of the history information and past behavior during the bucket loading. The system may be configured to teach the traction control procedure and adapt the parameter sets and/or definition of the parameter sets based on the history information.

**[0070]** It is to be appreciated that various further features may be complement or differentiate at least some of the above-illustrated embodiments. For example, there may be further user interaction and/or automation functionality further facilitating the operator to monitor and control the work machine during the bucket loading mode, select appropriate action to overcome an issue regarding e.g. traction control or boom trajectory/positioning, and control the work machine.

**[0071]** An electronic device comprising electronic circuitries may be an apparatus for realizing at least some embodiments illustrated above, such as the method illustrated in connection with Figure 2 and features illustrated for the control unit 30, 310. The apparatus may be comprised in at least one computing device connected to or integrated into a control system of the work machine. Such control system may be an intelligent on-board control system controlling operation of various sub-systems of the work machine, such as a hydraulic system, driveline, a motor, etc, in one example the sub-systems illustrated in Figure 3. Such control systems are often distributed and include many independent modules connected by a bus system of controller area network (CAN) nodes, for example.

**[0072]** Figure 5 illustrates a simplified example apparatus capable of supporting at least some embodiments of the present invention. Illustrated is a device 500, which may be configured to carry out at least some of the embodiments relating to the bucket loading specific traction related operations illustrated above. In some embodiments, the device 500 comprises or implements the control unit 30, or other module(s), functions and/or unit(s) for performing at least some of the above-illustrated embodiments.

**[0073]** Comprised in the device 500 is a processor 510, which may comprise, for example, a single- or multi-core processor. The processor 510 may comprise more than one processor. The processor may comprise at least one application-specific integrated circuit, ASIC. The processor may comprise at least one field-programmable gate array, FPGA. The processor may be configured, at least in part by computer instructions, to perform actions.

**[0074]** The device 500 may comprise memory 520. The memory may comprise random-access memory and/or permanent memory. The memory may be at least in part accessible to the processor 510. The memory may be at least in part comprised in the processor 510. The memory may be at least in part external to the device 500 but accessible to the device. The memory 520 may be means for storing information, such as parameters 522 affecting operations of the device. The parameter information in particular may comprise parameter information affecting the bucket loading specific traction control procedure related features, such as threshold values.

**[0075]** The memory 520 may be a non-transitory computer readable medium comprising computer program code 524 including computer instructions that the processor 510 is configured to execute. When computer instructions configured to cause the processor to perform certain actions are stored in the memory, and the device in overall is configured to run under the direction of the processor using computer instructions from the memory, the processor and/or its at least one processing core may be considered to be configured to perform said certain actions. The processor may, together with the memory and computer program code, form means for performing at least some of the above-illustrated method steps in the device.

**[0076]** The device 500 may comprise a communications unit 530 comprising a transmitter and/or a receiver. The transmitter and the receiver may be configured to transmit and receive, respectively, i.a. data and control commands within or outside the work machine. The transmitter and/or receiver may be configured to operate in accordance with global system for mobile communication, GSM, wideband code division multiple access, WCDMA, long term evolution, LTE, 3GPP new radio access technology (N-RAT), wireless local area network, WLAN, and/or Ethernet standards, for example. The device 500 may comprise a near-field communication, NFC, transceiver. The NFC transceiver may support at least one NFC technology, such as NFC, Bluetooth, or similar technologies.

**[0077]** The device 500 may comprise or be connected to a UI. The UI may comprise at least one of a display 540, a speaker, an input device 550 such as a keyboard, a joystick, a touchscreen, and/or a microphone. The UI may be configured to display views on the basis of above illustrated embodiments. A user may operate the device and control at least some of above illustrated features. In some embodiments, the user may control the work machine 10 via the UI, for example to manually drive the vehicle, operate a boom, initiate automatic loading, change driving mode, change display views, modify parameters 522, etc.

**[0078]** The processor 510, the memory 520, the communications unit 530 and the UI may be interconnected by electrical leads internal to the device 500 in a multitude of different ways. For example, each of the aforementioned devices may be separately connected to a master bus internal to the device, to allow for the devices to exchange information. However, as the skilled person will appreciate, this is only one example and depending on the embodiment various ways of interconnecting at least two of the aforementioned devices may be selected without departing from the scope of the present invention.

**[0079]** It is to be understood that the embodiments of the invention disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

**[0080]** Reference throughout this specification to one embodiment or an embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Where reference is made to a numerical value using a term such as, for example, about or substantially, the exact numerical value is also disclosed.

**[0081]** While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the scope of the invention as defined in the appended claims.

**[0082]** The verbs "to comprise" and "to include" are used in this document as open limitations that neither exclude nor require the existence of also un-recited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", that is, a singular form, throughout this document does not exclude a plurality.

## Claims

1. An apparatus comprising means configured for performing the steps of:
   detecting (200) a work machine (10) comprising an electric driveline (300), a boom (14), and a bucket (16) connected to the boom to enter a bucket loading mode, and initiating (210) a bucket loading specific traction control procedure in response to detecting the work machine to enter the bucket loading mode, the traction control procedure comprising the steps of:

   - receiving (220) driveline information of at least one component of the electric driveline, wherein the driveline information is information generated on the basis of signals from the at least one component of the electric driveline, and wherein the at least one component of the electric driveline is an inverter unit, an electric motor, a gearbox, or a transmission mechanism,
   - detecting (230) a wheel slip condition during the bucket loading mode solely on the basis of the received driveline information of the at least one component of the electric driveline and at least one slip condition threshold value preconfigured for the bucket loading mode,
   - defining (240) a bucket loading specific traction control parameter set in response to the detected slip condition, and
   - controlling (250) speed and torque of the electric driveline on the basis of the defined traction control parameter set,

   whereby no physical sensors are required for the bucket loading specific traction control procedure.

2. The apparatus of claim 1, wherein the driveline information is indicative of at least one of electric driveline rotational speed and torque status.

3. The apparatus of claim 1 or 2, wherein the means are further configured for

   - receiving wheel rotation information, and
   - detecting the slip condition during the bucket loading mode, in addition to the driveline information, further on the basis of the received wheel rotation information and a predefined wheel rotation threshold value preconfigured for the bucket loading mode.

4. The apparatus of any preceding claim, wherein the detecting (200) the work machine (10) to enter the bucket loading mode comprises detecting at least one of:

   - the work machine to enter a predefined bucket loading entry position,
   - the bucket at a position associated with start of bucket loading,
   - the boom at a position associated with the start of bucket loading,
   - an input from an operator to initiate bucket loading,
   - a joystick of the work machine at a position with the start of bucket loading, and
   - other work machine control system data asso-

ciated with bucket loading indicating entering or a need to enter the bucket loading mode.

**5.** The apparatus of any preceding claim, wherein the bucket loading specific traction control parameter set is defined (240) based on the driveline information, which comprises information from an inverter unit (302) and is indicative of one or more of electric motor speed, electric motor torque, electric motor power, electric motor current, electric motor voltage, electric supply side voltage, electric supply side current, and inverter internal limitation information.

**6.** The apparatus of any preceding claim, wherein the defined bucket loading specific traction control parameter set is indicative of one or more of electric motor power request, electric motor power limitation, electric motor torque limitation, electric motor torque request, speed request, speed request, speed limitation, and inverter internal limitation information.

**7.** The apparatus of any preceding claim, wherein the apparatus is configured to terminate the traction control procedure in response to detecting termination of the bucket loading mode.

**8.** The apparatus of any preceding claim, wherein the apparatus is configured to determine, during the bucket loading mode, if a change condition for changing the defined traction control parameter set or at least one parameter in the defined traction control parameter set is met, and the apparatus is configured to change the defined traction control parameter set or at least one parameter in the defined traction control parameter set in response to the change condition being met.

**9.** The apparatus of any preceding claim, wherein the apparatus is further configured to monitor at least the driveline information after the controlling on the basis of the defined traction control parameter set, and, in response to further detecting a slip condition, the apparatus is further configured to:

- define an updated traction control parameter set for controlling the speed and torque of the electric driveline to further reduce wheel slipping,
- define boom control parameter to reduce the wheel slipping, and/or
- define bucket control parameter to reduce the wheel slipping.

**10.** A work machine (10), comprising the apparatus of any preceding claim.

**11.** A method for controlling loading by a work machine (10), comprising the steps of:

detecting (200) that the work machine (10) comprises an electric driveline (300), a boom (14), and a bucket (16) connected to the boom to enter a bucket loading mode, and initiating (210) a bucket loading specific traction control procedure in response to detecting that the work machine (10) enters the bucket loading mode, the bucket loading specific traction control procedure comprising the steps of:

- receiving (220) driveline information of at least one component of the electric driveline, wherein the driveline information is information generated on the basis of signals from the at least one component of the electric driveline, and wherein the at least one component of the electric driveline is an inverter unit, an electric motor, a gearbox, or a transmission mechanism,
- detecting (230) a wheel slip condition during the bucket loading mode solely on the basis of the received driveline information of the at least one component of the electric driveline and at least one slip condition threshold value preconfigured for the bucket loading mode,
- defining (240) a bucket loading specific traction control parameter set in response to the detected slip condition, and
- controlling (250) speed and torque of the electric driveline on the basis of the defined traction control parameter set, whereby no physical sensors are required for the bucket loading specific traction control procedure.

**12.** The method of claim 11, wherein the bucket loading specific traction control parameter set is defined (240) based on the driveline information, which comprises information from an inverter unit (302) and is indicative of one or more of electric motor power, electric motor current, electric motor voltage, electric supply side voltage, electric supply side current, and inverter internal limitation information.

**13.** The method of claim 11 or 12, wherein the defined bucket loading specific traction control parameter set is indicative of one or more of electric motor power request, electric motor power limitation, electric motor torque limitation, electric motor torque request, speed request, speed request, speed limitation, and inverter internal limitation information.

**14.** The method of any preceding claim 11 to 13, further comprising: determining, during the bucket loading mode, if a change condition for changing the defined traction control parameter set or at least one parameter in the defined traction control parameter set is met, and changing the defined traction control parameter set or at least one parameter in the defined traction control parameter set in response to the change condition being met.

**15.** A computer program comprising code for, when executed in a data processing apparatus (500), causing a method in accordance with any one of claims 11 to 14 to be performed.

**Patentansprüche**

**1.** Einrichtung, die Mittel umfasst, die dazu ausgelegt sind, die folgenden Schritte durchzuführen:

Erfassen (200) einer Arbeitsmaschine (10), die eine elektrische Antriebswelle (300), einen Ausleger (14) und eine Schaufel (16), die mit dem Ausleger verbunden ist, um in einen Schaufelbeladungsmodus einzutreten, umfasst, und Einleiten (210) einer schaufelbeladungsspezifischen Traktionssteuerprozedur in Reaktion auf Erfassen der Arbeitsmaschine, um in den Schaufelbeladungsmodus einzutreten, wobei die Traktionssteuerprozedur die folgenden Schritte umfasst:

- Empfangen (220) von Antriebswelleninformationen von zumindest einer Komponente der elektrischen Antriebswelle, wobei die Antriebswelleninformationen Informationen sind, die auf der Basis von Signalen von der zumindest einen Komponente der elektrischen Antriebswelle erzeugt werden, und wobei die zumindest eine Komponente der elektrischen Antriebswelle eine Wechselrichtereinheit, ein Elektromotor, ein Getriebe oder ein Übersetzungsmechanismus ist,
- Erfassen (230) einer Radschlupfbedingung während des Schaufelbeladungsmodus ausschließlich auf der Basis der empfangenen Antriebswelleninformationen der zumindest einen Komponente der elektrischen Antriebswelle und zumindest eines Schlupfbedingungsschwellenwerts, der für den Schaufelbeladungsmodus vorab konfiguriert wurde,
- Definieren (240) eines schaufelbeladungsspezifischen Traktionssteuerparametersatzes in Reaktion auf die erfasste Schlupfbedingung, und
- Steuern (250) von Geschwindigkeit und Drehmoment der elektrischen Antriebswelle auf der Basis des definierten Traktionssteuerparametersatzes,

wobei keine physischen Sensoren für die schaufelbeladungsspezifische Traktionssteuerprozedur benötigt werden.

**2.** Einrichtung nach Anspruch 1, wobei die Antriebswelleninformationen zumindest eines von Drehgeschwindigkeit und Drehmomentstatus der elektrischen Antriebswelle angeben.

**3.** Einrichtung nach Anspruch 1 oder 2, wobei die Mittel weiter ausgelegt sind zum

- Empfangen von Radrotationsinformationen, und
- Erfassen der Schlupfbedingung während des Schaufelbeladungsmodus, zusätzlich zu den Antriebswelleninformationen, weiter auf der Basis der empfangenen Radrotationsinformationen und eines vordefinierten Radrotationsschwellenwerts, derfür den Schaufelbeladungsmodus vorab konfiguriert wurde.

**4.** Einrichtung nach einem vorstehenden Anspruch, wobei das Erfassen (200) der Arbeitsmaschine (10), um in den Schaufelbeladungsmodus einzutreten, Erfassen zumindest eines des Folgenden umfasst:

- der Arbeitsmaschine, um in eine vordefinierte Schaufelbeladungseingangsposition einzutreten,
- der Schaufel bei einer Position, die mit Beginn der Schaufelbeladung verknüpft ist,
- des Auslegers bei einer Position, die mit dem Beginn der Schaufelbeladung verknüpft ist,
- einer Eingabe von einem Operator, um Schaufelbeladung einzuleiten,
- eines Kurzhebels der Arbeitsmaschine bei einer Position mit dem Beginn der Schaufelbeladung, und
- anderer Arbeitsmaschinensteuersystemdaten, die mit Schaufelbeladung verknüpft sind, die Eintreten in den Schaufelbeladungsmodus oder einen Bedarf, in diesen einzutreten, angeben.

**5.** Einrichtung nach einem vorstehenden Anspruch, wobei der schaufelbeladungsspezifische Traktionssteuerparametersatz basierend auf den Antriebswelleninformationen definiert (240) ist, die Informationen von einer Wechselrichtereinheit (302) umfassen und eine oder mehrere von Elektromotorgeschwindigkeits-, Elektromotordrehmoments-, Elektromotorleistungs-, Elektromotorstromstärke-, Elektromotorspannungs-, stromversorgungsseitigen Spannungs-, stromversorgungsseitigen Stromstärke- und wechselrichterinternen Begrenzungsinformationen angeben.

**6.** Einrichtung nach einem vorstehenden Anspruch, wobei der definierte schaufelbeladungsspezifische Traktionssteuerparametersatz eine oder mehrere von Elektromotorleistungsanforderungs-, Elektromotorleistungsbegrenzungs-, Elektromotordrehmo-

mentbegrenzungs-, Elektromotordrehmomentanforderungs-, Geschwindigkeitsanforderungs-, Geschwindigkeitsanforderungs-, Geschwindigkeitsbegrenzungs- und wechselrichterinternen Begrenzungsinformationen angibt.

**7.** Einrichtung nach einem vorstehenden Anspruch, wobei die Einrichtung dazu ausgelegt ist, die Traktionssteuerprozedur in Reaktion auf Erfassen von Beendigung des Schaufelbeladungsmodus zu beenden.

**8.** Einrichtung nach einem vorstehenden Anspruch, wobei die Einrichtung dazu ausgelegt ist, während des Schaufelbeladungsmodus zu ermitteln, ob eine Änderungsbedingung zum Ändern des definierten Traktionssteuerparametersatzes oder zumindest eines Parameters in dem definierten Traktionssteuerparametersatz erfüllt ist, und die Einrichtung dazu ausgelegt ist, den definierten Traktionssteuerparametersatz oder zumindest einen Parameter in dem definierten Traktionssteuerparametersatz in Reaktion darauf, dass die Änderungsbedingung erfüllt ist, zu ändern.

**9.** Einrichtung nach einem vorstehenden Anspruch, wobei die Einrichtung weiter dazu ausgelegt ist, zumindest die Antriebswelleninformationen nach dem Steuern auf der Basis des definierten Traktionssteuerparametersatzes zu überwachen, und wobei in Reaktion auf weiteres Erfassen einer Schlupfbedingung die Einrichtung für Folgendes ausgelegt ist:

- Definieren eines aktualisierten Traktionssteuerparametersatzes zum Steuern der Geschwindigkeit und des Drehmoments der elektrischen Antriebswelle, um Radschlupf weiter zu verringern,
- Definieren vom Auslegersteuerparameter, um den Radschlupf zu verringern, und/oder
- Definieren vom Schaufelsteuerparameter, um den Radschlupf zu verringern.

**10.** Arbeitsmaschine (10), umfassend die Einrichtung nach einem vorstehenden Anspruch.

**11.** Verfahren zum Steuern vom Beladen durch eine Arbeitsmaschine (10), umfassend die folgenden Schritte:

Erfassen (200), dass die Arbeitsmaschine (10) eine elektrische Antriebswelle (300), einen Ausleger (14) und eine Schaufel (16), die mit dem Ausleger verbunden ist, um in einen Schaufelbeladungsmodus einzutreten, umfasst, und Einleiten (210) einer schaufelbeladungsspezifischen Traktionssteuerprozedur in Reaktion auf Erfassen, dass die Arbeitsmaschine (10) in den Schaufelbeladungsmodus eintritt, wobei die schaufelbeladungsspezifische Traktionssteuerprozedur die folgenden Schritte umfasst:

- Empfangen (220) von Antriebswelleninformationen von zumindest einer Komponente der elektrischen Antriebswelle, wobei die Antriebswelleninformationen Informationen sind, die auf der Basis von Signalen von der zumindest einen Komponente der elektrischen Antriebswelle erzeugt werden, und wobei die zumindest eine Komponente der elektrischen Antriebswelle eine Wechselrichtereinheit, ein Elektromotor, ein Getriebe oder ein Übersetzungsmechanismus ist,
- Erfassen (230) einer Radschlupfbedingung während des Schaufelbeladungsmodus ausschließlich auf der Basis der empfangenen Antriebswelleninformationen der zumindest einen Komponente der elektrischen Antriebswelle und zumindest eines Schlupfbedingungsschwellenwerts, der für den Schaufelbeladungsmodus vorab konfiguriert wurde,
- Definieren (240) eines schaufelbeladungsspezifischen Traktionssteuerparametersatzes in Reaktion auf die erfasste Schlupfbedingung, und
- Steuern (250) von Geschwindigkeit und Drehmoment der elektrischen Antriebswelle auf der Basis des definierten Traktionssteuerparametersatzes,

wobei keine physischen Sensoren für die schaufelbeladungsspezifische Traktionssteuerprozedur benötigt werden.

**12.** Verfahren nach Anspruch 11, wobei der schaufelbeladungsspezifische Traktionssteuerparametersatz basierend auf den Antriebswelleninformationen definiert (240) ist, die Informationen von einer Wechselrichtereinheit (302) umfassen und eine oder mehrere von Elektromotorleistungs-, Elektromotorstromstärke-, Elektromotorspannungs-, stromversorgungsseitigen Spannungs-, stromversorgungsseitigen Stromstärke- und wechselrichterinternen Begrenzungsinformationen angeben.

**13.** Verfahren nach Anspruch 11 oder 12, wobei der definierte schaufelbeladungsspezifische Traktionssteuerparametersatz eine oder mehrere von Elektromotorleistungsanforderungs-, Elektromotorleistungsbegrenzungs-, Elektromotordrehmomentbegrenzungs-, Elektromotordrehmomentanforderungs-, Geschwindigkeitsanforderungs-, Geschwindigkeitsanforderungs-, Geschwindigkeitsbegrenzungs- und wechselrichterinternen Begrenzungsin-

formationen angibt.

**14.** Verfahren nach einem vorstehenden Anspruch 11 bis 13, weiter umfassend: Ermitteln, während des Schaufelbeladungsmodus, ob eine Änderungsbedingung zum Ändern des definierten Traktionssteuerparametersatzes oder zumindest eines Parameters in dem definierten Traktionssteuerparametersatz erfüllt ist, und Ändern des definierten Traktionssteuerparametersatzes oder zumindest eines Parameters in dem definierten Traktionssteuerparametersatz in Reaktion darauf, dass die Änderungsbedingung erfüllt ist.

**15.** Computerprogramm, das Code umfasst, um, wenn er in einer Datenverarbeitungseinrichtung (500) ausgeführt wird, zu veranlassen, dass ein Verfahren in Übereinstimmung mit einem der Ansprüche 11 bis 14 durchgeführt wird.

**Revendications**

**1.** Appareil comprenant des moyens configurés pour effectuer les étapes consistant à :

détecter (200) une machine de travail (10) comprenant une chaîne cinématique électrique (300), une flèche (14) et un godet (16) relié à la flèche pour entrer dans un mode de chargement de godet, et initier (210) une procédure de commande de traction spécifique au chargement de godet en réponse à la détection de la machine de travail pour entrer dans le mode de chargement de godet, la procédure de commande de traction comprenant les étapes consistant à :

- recevoir (220) des informations de chaîne cinématique d'au moins un composant de la chaîne cinématique électrique, dans lequel les informations de chaîne cinématique sont des informations générées sur la base de signaux provenant du au moins un composant de la chaîne cinématique électrique, et dans lequel le au moins un composant de la chaîne cinématique électrique est une unité d'onduleur, un moteur électrique, une boîte de vitesses ou un mécanisme de chaîne cinématique,
- détecter (230) une condition de glissement de roue pendant le mode de chargement de godet uniquement sur la base des informations de chaîne cinématique reçues du au moins un composant de la chaîne cinématique électrique et d'au moins une valeur de seuil de condition de glissement préconfigurée pour le mode de chargement de godet,
- définir (240) un ensemble de paramètres de commande de traction spécifique au chargement de godet en réponse à la condition de glissement détectée, et
- commander (250) la vitesse et le couple de la chaîne cinématique électrique sur la base de l'ensemble de paramètres de commande de traction défini,

selon lequel aucun capteur physique n'est requis pour la procédure de commande de traction spécifique au chargement de godet.

**2.** Appareil selon la revendication 1, dans lequel les informations de chaîne cinématique indiquent au moins un parmi la vitesse de rotation et l'état de couple de la chaîne cinématique électrique.

**3.** Appareil selon la revendication 1 ou 2, dans lequel les moyens sont en outre configurés pour

- recevoir des informations de rotation de roue, et
- détecter la condition de glissement pendant le mode de chargement de godet, en plus des informations de chaîne cinématique, en outre sur la base des informations de rotation de roue reçues et d'une valeur de seuil de rotation de roue prédéfinie préconfigurée pour le mode de chargement de godet.

**4.** Appareil selon une quelconque revendication précédente, dans lequel la détection (200) de la machine de travail (10) pour entrer dans le mode de chargement de godet comprend la détection d'au moins un parmi :

- la machine de travail pour entrer une position d'entrée de chargement de godet prédéfinie,
- le godet dans une position associée au début du chargement de godet,
- la flèche dans une position associée au début du chargement de godet,
- une entrée d'un opérateur pour initier un chargement de godet,
- une manette de la machine de travail dans une position avec le début du chargement de godet, et
- d'autres données du système de commande de machine de travail associées au chargement de godet indiquant l'entrée ou la nécessité d'entrer dans le mode de chargement de godet.

**5.** Appareil selon une quelconque revendication précédente, dans lequel l'ensemble de paramètres de commande de traction spécifique au chargement de godet est défini (240) sur la base des informations de chaîne cinématique, qui comprennent des infor-

mations provenant d'une unité d'onduleur (302) et indiquent un ou plusieurs parmi une vitesse de moteur électrique, un couple de moteur électrique, une puissance de moteur électrique, un courant de moteur électrique, une tension de moteur électrique, une tension côté alimentation électrique, un courant côté alimentation électrique et des informations de limitation interne d'onduleur.

**6.** Appareil selon une quelconque revendication précédente, dans lequel l'ensemble défini de paramètres de commande de traction spécifiques au chargement de godet est indicatif d'une ou plusieurs parmi une demande de puissance de moteur électrique, une limitation de puissance de moteur électrique, une limitation de couple de moteur électrique, une demande de couple de moteur électrique, une demande de vitesse, une demande de vitesse, une limitation de vitesse et une information de limitation interne d'onduleur.

**7.** Appareil selon une quelconque revendication précédente, dans lequel l'appareil est configuré pour mettre fin à la procédure de commande de traction en réponse à la détection de la fin du mode de chargement de godet.

**8.** Appareil selon une quelconque revendication précédente, dans lequel l'appareil est configuré pour déterminer, pendant le mode de chargement de godet, si une condition de changement pour changer l'ensemble de paramètres de commande de traction défini ou au moins un paramètre dans l'ensemble de paramètres de commande de traction défini est remplie ou non, et l'appareil est configuré pour changer l'ensemble de paramètres de commande de traction défini ou au moins un paramètre dans l'ensemble de paramètres de commande de traction défini en réponse à la condition de changement remplie.

**9.** Appareil selon une quelconque revendication précédente, dans lequel l'appareil est en outre configuré pour surveiller au moins les informations de chaîne cinématique après la commande sur la base de l'ensemble de paramètres de commande de traction défini, et, en réponse à une détection supplémentaire d'une condition de glissement, l'appareil est en outre configuré pour :

- définir un ensemble de paramètres de commande de traction mis à jour pour commander la vitesse et le couple de la chaîne cinématique électrique afin de réduire davantage un glissement de roue,
- définir un paramètre de commande de la flèche pour réduire un glissement de roue, et/ou
- définir un paramètre de commande de godet pour réduire un glissement de roue.

**10.** Machine de travail (10), comprenant l'appareil selon une quelconque revendication précédente.

**11.** Procédé de commande de chargement par une machine de travail (10), comprenant les étapes consistant à :

détecter (200) que la machine de travail (10) comprend une chaîne cinématique électrique (300), une flèche (14) et un godet (16) relié à la flèche pour entrer dans un mode de chargement de godet, et initier (210) une procédure de commande de traction spécifique au chargement de godet en réponse à la détection que la machine de travail (10) entre dans le mode de chargement de godet, la procédure de commande de traction spécifique au chargement de godet comprenant les étapes consistant à :

- recevoir (220) des informations de chaîne cinématique d'au moins un composant de la chaîne cinématique électrique, dans lequel les informations de chaîne cinématique sont des informations générées sur la base de signaux provenant du au moins un composant de la chaîne cinématique électrique, et dans lequel le au moins un composant de la chaîne cinématique électrique est une unité d'onduleur, un moteur électrique, une boîte de vitesses ou un mécanisme de chaîne cinématique,
- détecter (230) une condition de glissement de roue pendant le mode de chargement de godet uniquement sur la base des informations de chaîne cinématique reçues du au moins un composant de la chaîne cinématique électrique et d'au moins une valeur de seuil de condition de glissement préconfigurée pour le mode de chargement de godet,
- définir (240) un ensemble de paramètres de commande de traction spécifique au chargement de godet en réponse à la condition de glissement détectée, et
- commander (250) la vitesse et le couple de la chaîne cinématique électrique sur la base de l'ensemble de paramètres de commande de traction défini,

selon lequel aucun capteur physique n'est requis pour la procédure de commande de traction spécifique au chargement de godet.

**12.** Procédé selon la revendication 11, dans lequel l'ensemble de paramètres de commande de traction spécifique au chargement de godet est défini (240) sur la base des informations de chaîne cinématique, qui comprennent des informations provenant d'une

unité d'onduleur (302) et indiquent un ou plusieurs parmi une puissance de moteur électrique, un courant de moteur électrique, une tension de moteur électrique, une tension côté alimentation électrique, un courant côté alimentation électrique et des informations de limitation interne d'onduleur.

**13.** Procédé selon la revendication 11 ou 12, dans lequel l'ensemble défini de paramètres de commande de traction spécifiques au chargement de godet est indicatif d'une ou plusieurs parmi une demande de puissance de moteur électrique, une limitation de puissance de moteur électrique, une limitation de couple de moteur électrique, une demande de couple de moteur électrique, une demande de vitesse, une demande de vitesse, une limitation de vitesse et une information de limitation interne d'onduleur.

**14.** Procédé selon une quelconque revendication précédente 11 à 13, comprenant en outre : une détermination, pendant le mode de chargement de godet, qu'une condition de changement pour changer l'ensemble de paramètres de commande de traction défini ou au moins un paramètre dans l'ensemble de paramètres de commande de traction défini est remplie ou non, et un changement de l'ensemble de paramètres de commande de traction défini ou d'au moins un paramètre dans l'ensemble de paramètres de commande de traction défini en réponse à la condition de changement qui est remplie.

**15.** Programme informatique comprenant un code pour, lorsqu'il est exécuté dans un appareil de traitement de données (500), amener un procédé selon l'une quelconque des revendications 11 à 14 à être exécuté.

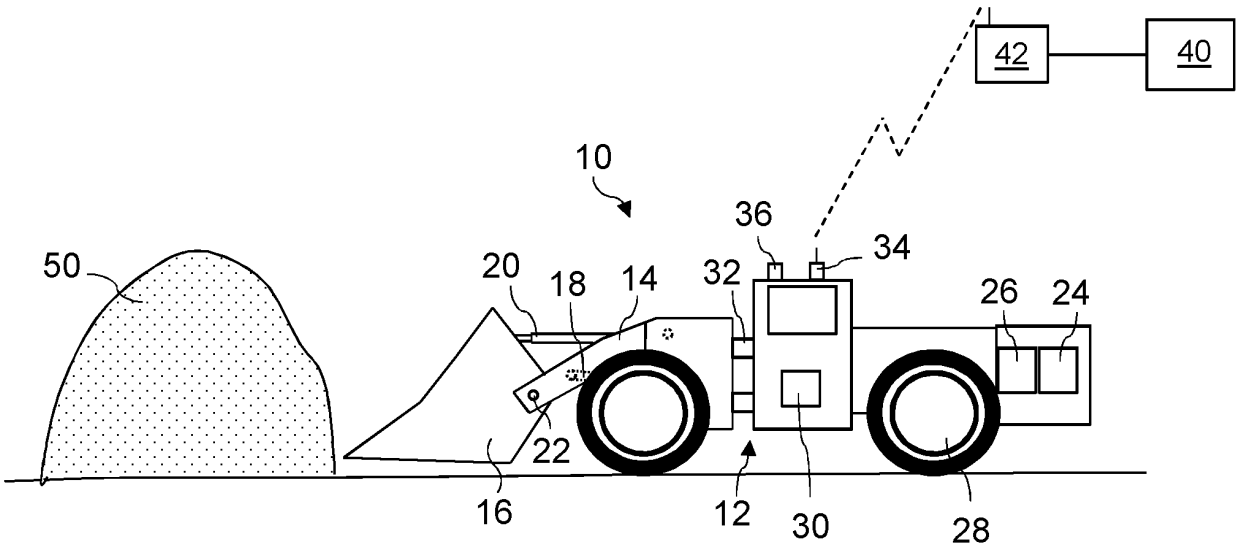


Fig. 1

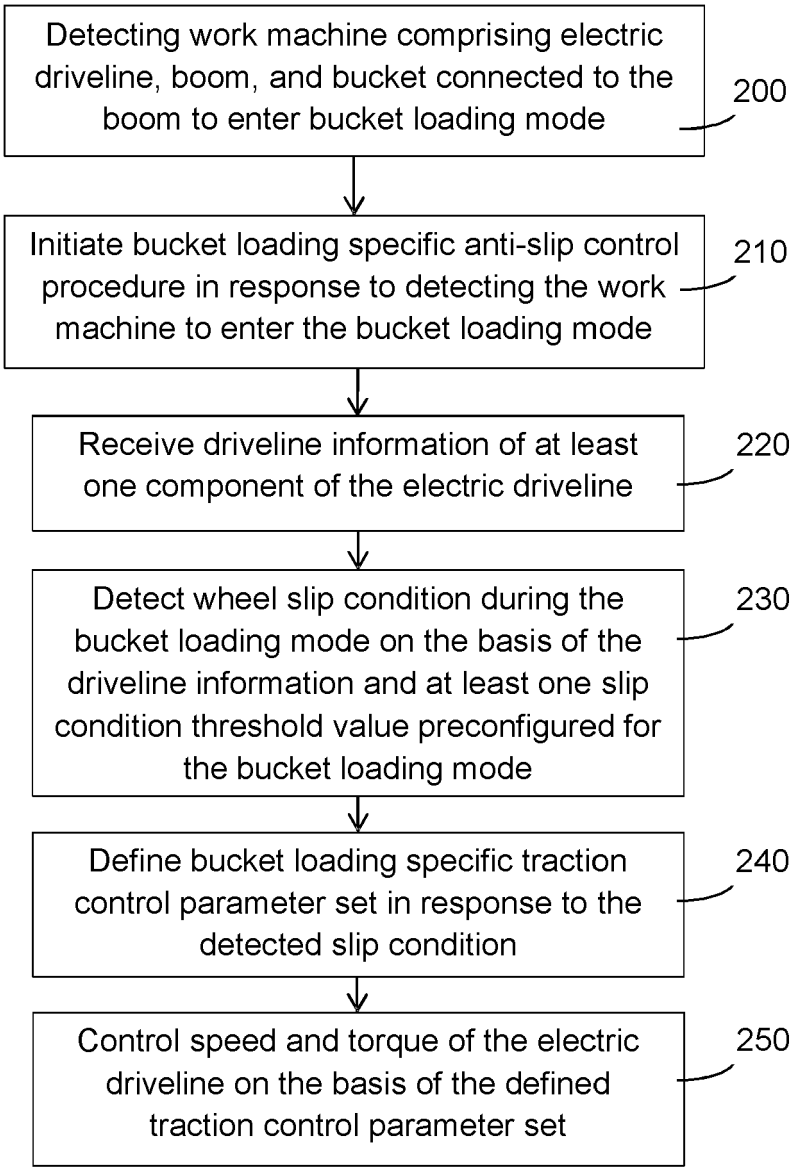
Detecting work machine comprising electric driveline, boom, and bucket connected to the boom to enter bucket loading mode
200
Initiate bucket loading specific anti-slip control procedure in response to detecting the work machine to enter the bucket loading mode
210
Receive driveline information of at least one component of the electric driveline
220
Detect wheel slip condition during the bucket loading mode on the basis of the driveline information and at least one slip condition threshold value preconfigured for the bucket loading mode
230
Define bucket loading specific traction control parameter set in response to the detected slip condition
240
Control speed and torque of the electric driveline on the basis of the defined traction control parameter set
250

Fig. 2

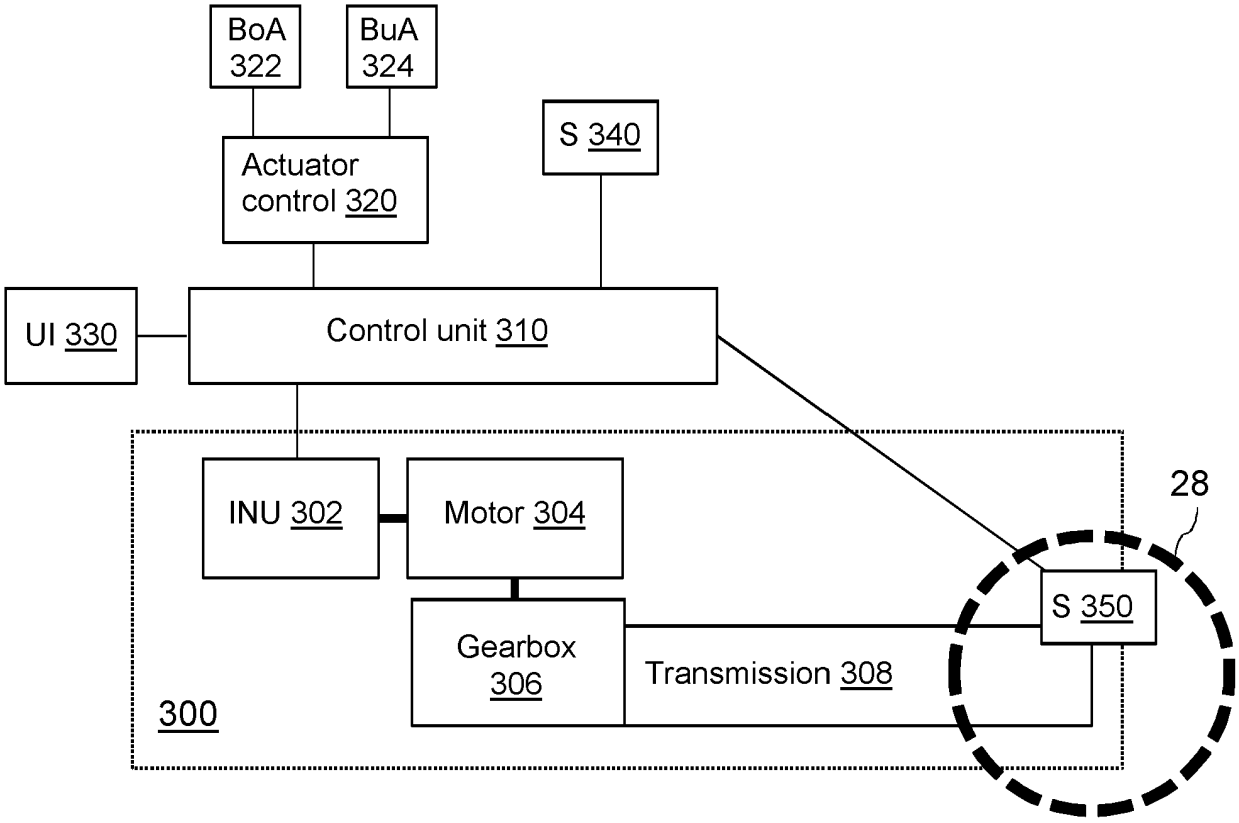
BoA
322
BuA
324
S 340
Actuator
control 320
UI 330
Control unit 310
INU 302
Motor 304
28
S 350
Gearbox
306
Transmission 308
300

Fig. 3

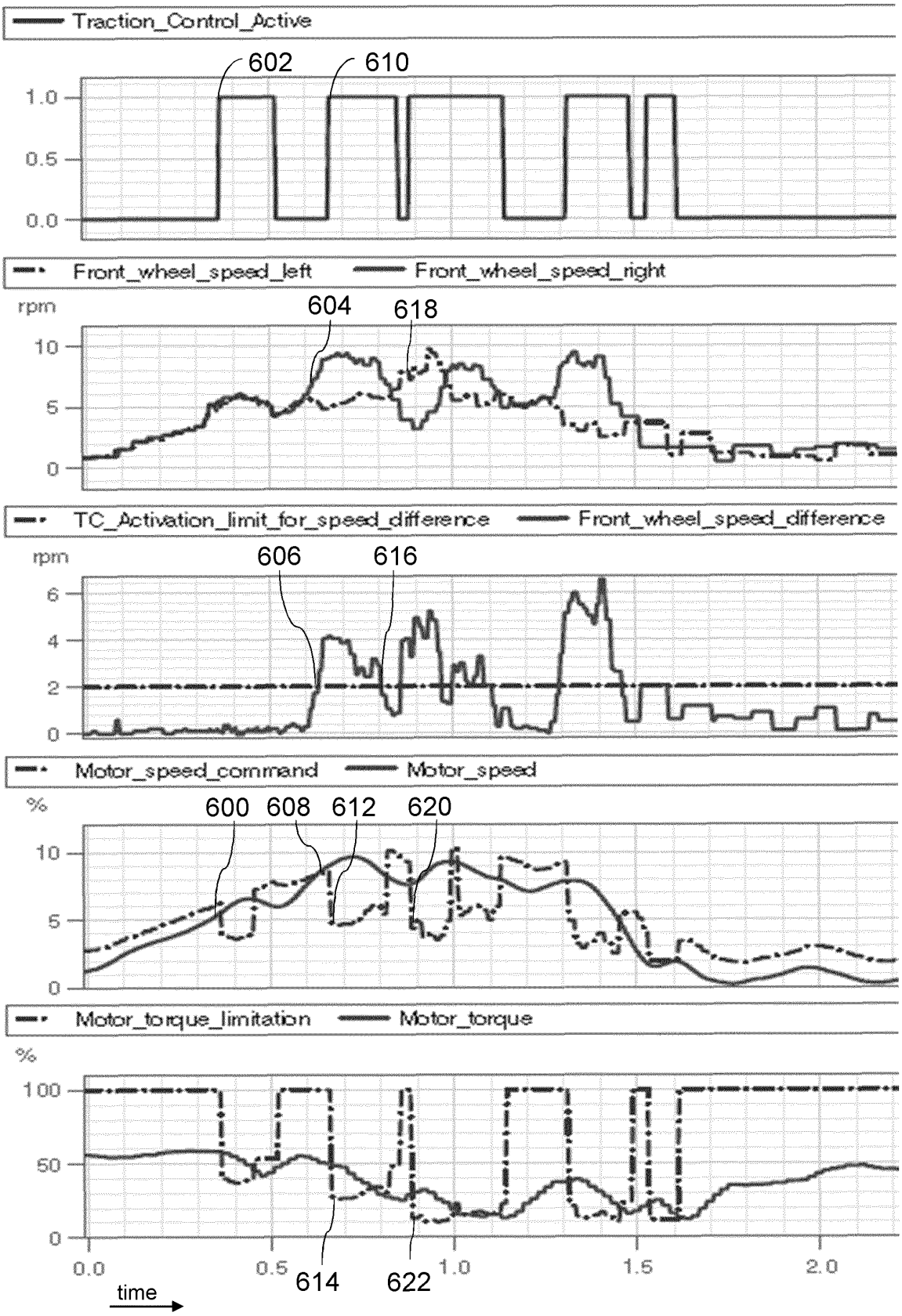
Traction_Control_Active
602
610
1.0
0.5
0.0
Front_wheel_speed_left
Front_wheel_speed_right
rpm
604
618
10
5
0
TC_Activation_limit_for_speed_difference
Front_wheel_speed_difference
rpm
606
616
6
4
2
0
Motor_speed_command
Motor_speed
%
600
608
612
620
10
5
0
Motor_torque_limitation
Motor_torque
%
100
50
0
0.0
0.5
1.0
1.5
2.0
614
622
time

Fig. 4

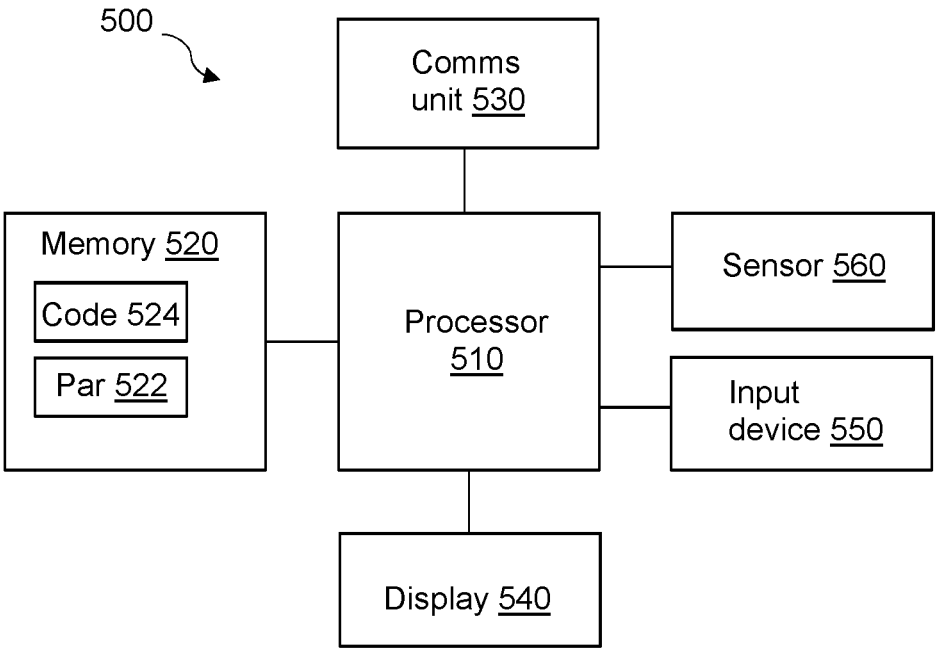
500
Comms unit 530
Memory 520
Code 524
Par 522
Processor 510
Sensor 560
Input device 550
Display 540

Fig. 5

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- EP 3207187 A **[0004]**