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The present invention relates to an agricultural work machine, in particular in the form of a harvester and/or of a soil cultivating machine attachable to a tractor, having at least one work unit and/or adjustment unit that can be driven by a drive for carrying out an agricultural function, wherein the drive has at least one electric motor and wherein a regulation apparatus is provided for regulating the speed and/or the torque of the drive.

With agricultural attachment items such as a self-loading wagon, a reaping machine or a hay-making machine in the form of a tedder or of a swather, or with a soil cultivating machine such as a rotary harrow, the work units which carry out the agricultural functions of the respective work units are usually driven by a mechanical drive which is fed via a cardan shaft from the power take-off shaft of the tractor. It has alternatively also been proposed to provide hydraulic drives in the form of hydraulic motors. Said agricultural functions are, for example, the harvest processing which, in the case of a self-loading wagon, includes the picking up of the harvest from the ground by a pick-up spiked roller and the conveying of the picked up harvest into a harvest store by means of a conveying rotor and also includes the unloading of the harvest by means of doctor rolls. With a reaping machine, the stalk material of different height and/or different density has to be cut off and, optionally, conditioned by means of a conditioner connected downstream and conveyed laterally away by means of a transverse conveyor belt to place the cut-off stalk material and leaf material in a swath. With correspondingly different attachment items, correspondingly different agricultural functions have to be carried out, with "agricultural functions" in particular meaning the key tasks of the respective attachment item that typically require a higher power take-up and a varying external load by field conditions, harvest conditions and/or soil cultivating conditions.

The use of electric motors has also sporadically been proposed for the work units of agricultural machinery in recent times, and indeed for their driving. DC motors having a supply voltage of 12 VDC are typically used here in which a speed feedback is provided to be able to determine the rotational position or the speed of the motor and of the unit connected thereto.

DE 10 2007 024 644 A1, for example, shows a tractor that is provided with a power electronics interface for this purpose to be able to feed the work units of diverse agricultural machinery driven by electric motors. DE 10 2007 038 510 A1 furthermore shows a fertilizer distributor in which the distribution members are driven by an electric motor. DE 10 2007 024 645 A1 furthermore describes an electric attachment item having an electric drive which is supplied with power from the tractor. DE 10 2005 019 362 describes the more detailed embodiment of an electric interface for transferring electrical energy between a tractor and an agricultural work unit couplable thereto. DE 10303050 A1 furthermore proposes coupling a generator to the power take-off shaft of the tractor to supply an attachment item with sufficient electrical energy, said generator driving electrical loads of the tractor and of the attachment item at a generator voltage that is considerably above the typical 12V onboard voltage of tractors.

Furthermore WO2010/122055 A1, that was published after the priority date of the present application, shows a harvester having an electrically driven drum whose drive can be configured without sensors.

EP 2 220 928 A1 discloses an agricultural attachment item that is driven by an electric motor.

EP 0 864 457 A2 describes a drive system for utility vehicles in which sensor-less electric motors are disclosed.

EP 1 645 456 A2 shows an agricultural work machine that reduces its travel speed if it is found that, for example, a reaping blade of a mower has a greater cutting resistance due to denser grass.

To be able to adapt the work unit to varying loads, travel speeds, and field conditions, the torque and the speed of the drives are varied and are typically regulated by a regulation apparatus in dependence on different operating parameters. The speed of the work unit or of its drive has to be determined for this purpose. If the respective work unit is adjusted step-wise, for example if the scraper floor of a self-loading wagon is

driven backward a little to reduce the pressure at the front end of the feed store, the rotational position of the drive or of the electric motor moreover also has to be determined so that the regulation apparatus can directly power the unit up to the respective determined desired value.

The rotary encoders typically provided at the electric motors for this purpose are not only susceptible to problems in the rough agricultural working conditions the machines are exposed to, but also increase the required construction space for the electric drive that is actually not available with work units having roll-shaped or rotor-shaped drive parts such as the cutting rotor of a mower, the pick-up rotor of a self-loading wagon, or the swather socket of a hay-making machine since the electric motor there has to be integrated in the interior of the roll-shaped or rotor-shaped drive part for protection from the rough environmental conditions.

Starting from this, it is the underlying object of the present invention to provide an improved agricultural work machine of the named type which avoids disadvantages of the prior art and further develops the latter in an advantageous manner. The sensitivity of the speed determination and/or torque determination under rough agricultural conditions should in particular be reduced and the space for the electric motor and its wiring required at the drive parts of the agricultural work unit should be reduced without sacrificing a precise regulating capability of the drive.

This object is achieved in accordance with the invention by an agricultural work machine in accordance with claim 1. Preferred embodiments of the invention are the subject of the dependent claims.

It is therefore inter alia proposed to eliminate the rotary encoders typically used at the electric motors and to determine the rotor position of the electric motor by the phasing of the three-phase voltage network. This alternating field migrates with the poles around the periphery of the motor, whereby the rotational position and the speed of the motor can be determined. In accordance with the invention, the electric motor is configured without rotary encoders, with the regulation apparatus having a

determination device for determining the rotational position and the speed of the electric motor from the phasing of the three-phase voltage network applied to the electric motor. The typical rotary encoder sensor systems and mechanical speed sensors at the electric motor and at their signal lines can hereby be dispensed with, whereby the electric motor can be configured in a more compact manner and can be used better in installation situations having restricted available space and sensitivity toward rough operating conditions is reduced.

The determination of the rotational position and of the speed of the electric motor from the phasing of the three-phase voltage network applied to the electric motor can generally take place in different manners. The determination device can in particular comprise detection means for detecting the spatial, magnetic conductance fluctuations from which the rotational position of the electric motor can be determined. A power increase and/or the voltage of the intermediate circuit and/or the current switched state of the inverter can preferably be detected in this manner by means of suitable detection means, from which then the determination means determine the conductance fluctuation from which the rotational position of the electric motor is then calculated.

Sensor-less speed determination in electric motors is already known per se and is frequently used in drives for model-building techniques, for example. Sensor-less speed determination can, however. surprisingly also be used excellently for the regulation of electrical drives for the work units or adjustment units of agricultural work machines where special advantages result due to the reduced sensitivity of the sensor system and the reduced space requirements. Reference is made to the documents AT 502 615 B1 and AT 406 722 B with respect to the specific configuration of said determination device for determining the rotational position and speed of the electric motor from the phasing of the three-phase voltage network applied to the electric motor.

To fully decouple the electronics of the regulation and of the rotational position determination and speed determination from the electric motor and its installed position, provision can be made in an advantageous further development of the

invention that the regulating apparatus, including the aforesaid determination device for determining the rotational position and speed, forms an assembly that is formed separately from the electric motor, that is releasable from the electric motor, and that is connectable to the electric motor by the inverter of the power electronics. The electric motor is therefore advantageously configured as sensor-less on the motor side of the inverter or between the frequency inverter and the electric motor. Sensor-less here does not necessarily means that every kind of sensor is dispensed with; for example, temperature sensors for a temperature measurement of the winding temperature, for example, can by all means be provided. Rotary encoders and other sensors for determining the rotor position, the rotor speed or the rotor torque can, however, be dispensed with. The determination of the phasing of the three-phase voltage network and the determination of the rotational position and the speed of the electric motor from this take place on the side of the assemblies of the power electronics and control electronics connected upstream of the inverter.

Alternatively to a configuration with separate assemblies, however, in a further development of the invention, a complete drive can also be provided in which a motor that is sensor-less with respect to the speed and to the torque and which has a frequency inverter is combined to a closed assembly.

In a further development of the invention, said regulation apparatus and/or the aforesaid determination device together with the inverter of the power electronics can form a modular assembly that is connected to the voltage supply at the input side and that is connected to the electric motor at the output side. Said assembly can advantageously receive a desired speed and/or a desired torque as the input signal. The rotor position and/or the speed together with the current values and/or voltage values occurring at the inverter can be determined therefrom by said determination device and the regulator for the speed or torque regulation can then generate a corresponding signal for the inverter from them.

The agricultural machine itself can then generally be provided in different embodiments in said manner with an electric motor for driving the work unit and with a

self-learning regulation device. In accordance with the invention, the attachment item is designed as a self-loading wagon that has a pick-up with a spiked roller for picking up harvest from the ground. In accordance with a further development of the invention, the self-loading wagon further has a conveyor rotor for conveying the picked-up harvest into a harvest store and/or a doctor roll for unloading the harvest from the harvest store, wherein the electric drive comprising an electric motor and a transmission optionally associated therewith can drive said spiked roller, the conveyor rotor and/or the doctor roll. The regulation can here regulate the respective electric motor in said manner. Alternatively or additionally to the electric motor drive of the spiked roller of the pick-up, of the conveyor rotor and/or of said doctor roll, in a further development of the invention, the drive of a scraper floor and/or the drive of a transverse conveyor belt can also be provided in a corresponding manner with an electric motor that is regulated in said manner and that has the aforesaid determination device for determining the rotational position and speed of the electric motor from the phasing of the three-phase voltage network.

The use of an electric motor having an associated self-learning regulator is likewise advantageous in accordance with an illustrative example in a mower that can be attached to a tractor. The electric motor can here drive the work body of the blade rotor and/or a conditioner roller connected downstream and/or a transverse conveyor connected downstream and can be regulated by the regulator in said manner.

A further advantageous use is, in accordance with an illustrative example, a hay-making machine in the form of a swather or of a tedder which has at least one rotary rake which can be driven about an upright axis. The electric motor drives the rotary rake and is regulated in said manner to cope with harvest swaths of different thicknesses and/or densities and/or with harvest layers lying on the ground.

In accordance with a further illustrative example, a rotary harrow is furthermore provided whose rake prongs can be driven around typically upright axes of rotation by an electric motor that is regulated in said manner by the regulator to hold the rotary harrow at the ideal operating point despite varying ground properties. Alternatively or

additionally to the electric motor drive of the rake prongs, a trailing unit such as a cage roller can also be driven by an electric motor that is regulated in said manner.

A fourth illustrative example is a sowing machine or a seed drill whose metering wheels can be driven by an electric motor. Depending on the desired seed output that may vary for different field sections, said metering wheels are regulated to the desired speed by the regulation device via the respective electric motor. Alternatively or additionally to such a driving of the metering wheels by an electric motor, a tire packer unit of the sowing machine or seed drill can also be driven by an electric motor that is regulated by the regulator to hold the machine at the ideal operating point, in particular at ideal travel speed, despite varying travel resistance, for example when driving on slopes or when cornering.

The use of the electric motor free of rotary encoders is particularly advantageous when the electric drive is arranged in a roll-shape and/or tubular drive part of the work unit or in its interior.

The present invention will be explained in more detail in the following with reference to a preferred embodiment and to associated drawings. There are shown in the drawings:

Figure 1: a schematic side view of a self-loading wagon that is attached to a tractor at the rear side, with the self-loading wagon having a pick-up apparatus that is drivable by an electric motor and a metering apparatus that is drivable by an electric motor, and of a mower attachable to a tractor at the front side, with the rotors of the mower respectively being driven by an electric drive and regulated by means of a regulator;

Figure 2: a plan view of a hay-making machine attachable to a tractor at the rear side in the form of a swather that has four swath rakes that are driven by an electric drive and are regulated by a self-learning regulator;

Figure 3: a schematic plan view of a soil cultivating machine attached to a tractor at the rear side in the form of a rotary harrow whose rake prongs and whose cage roller are driven by electric motors and are regulated by means of a self-learning regulator;

Figure 4: a schematic side view of a sowing machine combination attached to a tractor at the rear side that has the metering wheels driven by an electric motor and a packer wheel unit driven by an electric motor that are speed-regulated via a regulator; and

Figure 5: a schematic representation of the electronic assembly for determining the rotational position and the speed of the electric motor from the phasing of the three-phase voltage network that is associated with the frequency inverter of the power electronics in the drawn embodiment.

A first attachment item 2 in the form of a harvester, said attachment item being configured in accordance with the invention in the form of a self-loading wagon 20, and a second attachment item 2 in the form of a front mower 60 are attached to the tractor 1 shown in Fig. 1.

The self-loading wagon 2 shown in Fig. 1 in this respect includes a plurality of work units 3 which each include a rotatably supported work body 4. A first work unit 3 in this respect forms the pick-up 17 including a spiked roller 9 for collecting harvest from the ground. The spiked roller 9, that may be suspended in an oscillating manner in the drawn embodiment, is here rotationally driven to convey harvest lying on the ground into a conveying channel. Said spiked roller 9 can, in a further development of the invention, include a tubular work body 4 from whose periphery spike-shaped entrainer spikes project.

A further work unit 3 is a conveyor comprising a conveyor rotor 10 which takes over the harvest picked up by the pick-up 17 and conveys it into the harvest store 11 of the self-loading wagon 20. The conveyor rotor 10 can, in a further development of the

invention, include a tubular work body 4 from whose periphery rotor spikes project which convey the harvest.

A further work unit 3 of the self-loading wagon 20 is furthermore a scraper floor 200 with which the harvest conveyed into the harvest store 11 can be distributed in said harvest store 11 and can be transported to a store wall at the rear side or to an unloading outlet provided there. Said scraper floor 200 likewise comprises a rotationally drivable drive element 201, for example in the form of a pinion, with which a continuously revolving drive member of the scraper floor can be driven. Said drive element 201 can here, for example, be seated on a shaft-like or tubular drive element that extends transversely over the ground.

A further work unit 3 is a metering apparatus 300 which is arranged at the harvest store 11 at the rear side and which can comprise a plurality of doctor rolls, for example, by means of which the harvest can be exactly metered on the unloading from the harvest store 11. Said doctor rolls of the metering apparatus 300 can likewise comprise a tubular work body 4 that can comprise entrainers attached to the outer periphery.

To drive said work bodies 4 of the work units, an electric motor 6 is respectively seated in the interior of the respective work body 4 in the drawn embodiment, said electric motor 6 advantageously being completely received in the interior of the respective work body 4 and being completely enclosed by the tubular or roll-shaped work body 4 at least at the peripheral side. The electric motor 6 can in particular be directly seated on the axle of the tubular work body 4 that also supports and rotatably bears said work body 4. Alternatively to such a tubular motor, however, a conventional inner rotor motor can also be used. Said tubular motor that is received in the interior of the respective work body is, however, preferred since it provides advantages with respect to space requirements and protection for the motor. The electric motor 6 can, however, also be installed without such a tubular jacket in dependence on the installation situation, in particular when the work unit to be driven does not comprise any tubular work body.

The electric motor 6 can here be connected to a transmission, not shown separately, for example in the form of a multistage planetary transmission, that is advantageously likewise supported on said axle and that can likewise be received in the interior of the work body in a further development of the invention.

The electric motor 6 of the respective drive is here regulated with respect to speed and torque by a regulation apparatus 30 to adapt the work movement of the respective work unit to the operating conditions, in particular to the size and density of a harvest swath to be picked up, and to the travel speed of the tractor. Depending on the respective operating parameters such as the swath size, swath density, and travel speed, the regulation apparatus 30 specifies a desired speed or a desired torque for the respective electric motor 6.

To be able to regulate the respective electric motor 6 to said desired speed or desired torque, the rotational position and the speed of the respective electric motor 6 is determined, and indeed by a determination device 31 that is combined in the drawn embodiment in accordance with Figure 5 together with the inverter 40 to form an electronic assembly that receives the desired speed or the desired torque at the input side and the voltage supply at the side of the inverter 40, while it controls the electric motor 6 at the output side that is itself configured as sensor-free or free of rotary encoders.

Said determination device 31 here comprises determination means 32 for determining the spatial magnetic conductance fluctuations from which the rotational position of the electric motor 6 can be determined, with detection means preferably being provided for detecting an intermediate circuit power increase and/or an intermediate circuit voltage and/or a current switched state of the inverter 40, from which then the conductance fluctuation can be determined by the determination means 32. A procedure such as explained in more detail in document AT 502 615 B1 or in document AT 406 722 B can be followed for the determination of the rotor position and the speed.

As Fig. 5 shows, the determined rotational position and the determined speed are processed by the regulator 22 and used to control the inverter 40 to regulate the electric motor 6 to the desired speed and/or to the desired torque.

The regulator 22 can vary the drive speed of the electric motors 6 of the work units to react to or to compensate variations of the outer load. If, for example, the harvest swath to be picked up becomes larger, whereby the power consumption of the electric motor 6 of the spiked roller 9 and/or of the conveyor rotor 10 increases, the regulator 22 can increase the speed of the electric motor 6 to cope with the increasing harvest stream.

Alternatively or additionally, the regulator 22 can also provide an adjustment signal for the travel speed of the tractor to change the travel speed of the tractor and to adapt it to the varying harvest stream. This adjustment signal can either be provided in the form of a display so that the operator implements the adjustment signal. Alternatively, a semi-automatic or fully automatic implementation by a travel speed regulator can also be provided.

If, for example, the harvest swath that is to be picked up by the self-loading wagon 2 becomes smaller, the regulator 22 can increase the travel speed to operate the self-loading wagon 2 while using its performance capability as completely as possible. The becoming smaller of the harvest stream or harvest swath is here determined by a drop in the power consumption of the electric motor 6 of the spiked roller 9 and/or of the conveyor rotor 10.

In a similar manner, the further work units 3 of the self-loading wagon 20 and the work units 3 of other harvesters or soil-cultivating machines can also be regulated by means of a drive 5 having an electric motor 6 and by means of a corresponding regulator 22, as the further Figures show.

For example, instead of the self-loading wagon 20 shown in Fig. 1, a baler can have electric motors regulated in a corresponding manner, for example for driving the spiked

roller of the pick-up of the press and/or for driving the conveyor rotor by which the harvest is conveyed into the pressing chamber and/or for driving the work units of the pressing apparatus.

The mower 60 attached at the front shown in Fig. 1 can include in a manner known per se a plurality of blade drums or blade rotors 13 which can be driven about upright axes and have radially projecting or outwardly pivotable blades to cut the standing harvest.

Said blade rotors 13 can, in a similar manner to the self-loading wagon 2, have tubular work bodies 4 in whose inner spaces an electric motor 6 and a transmission can be arranged in the manner shown in Fig. 2 to drive the blade rotors 13.

Without being drawn separately, the mower 60 in accordance with the drawn embodiment, can also include a conditioner roller connected downstream of the blade rotors 13 which conditions the cut harvest by mechanical processing, in particular kinks and/or breaks open the surface, to enable a faster drying. Said conditioner roller advantageously likewise comprises a work body in which a drive comprising an electric motor and, optionally, a transmission is integrated.

The mower 60 can furthermore be provided with a transverse conveyor, for example in the form of a transverse conveyor belt, that is connected downstream of said conditioner roller and conveys the cut and conditioned harvest transversely to the direction of travel, for example, to move it out of the track of the tractor. Said transverse conveyor can advantageously likewise comprise a work body, for example in the form of deflection pulleys, about which the transverse conveyor belt revolves and which are drivable by a drive comprising an electric motor and, optionally, a transmission.

The electric motors 6 of the blade rotors 13 and/or of the conditioner roller and/or of the transverse conveyor can be controlled by a regulator 22 in the previously described manner to react to and/or to compensate variations of the outer load in that the power consumption of the electric motor 6 is monitored and is correspondingly regulated.

Varying outer loads can be caused, for example, by a differently dense and/or high growth of the field to be reaped.

As Fig. 2 shows, the attachment item 2 can also be configured as a hay-making machine in the form of a swather which, in the drawn embodiment, has four rotary rakes 16 rotationally drivable about a respective upright axis. Said rotary rakes 16 of the hay-making machine 23 can here each comprise a drive body 4 in which a drive 5 having an electric motor 6 and, optionally, a transmission are integrated. The electric motor 6 is regulated by means of the already explained regulator 22.

As Fig. 3 shows, the attachment item 2 can also be formed as a rotary harrow which, in the drawn embodiment, has a row of tine rotors 25 aligned transversely to the direction of travel which are each rotationally drivable about an upright axis. Said tine rotors in this respect each include harrow spikes directed downwardly toward the ground as well as a working body 4 in which a drive 5 having an electric motor 6 and, optionally, a transmission are integrated. The rotary harrow can here have an electric motor 6 separately for each tine rotor. Alternatively, individual tine rotors or a plurality of tine rotors can also be combined into a group which is driven by an electric motor in the work body of a tine rotor. As Fig. 3 shows, a roll 26 trails the harrow spikes 25 and can optionally be configured as drivable by a roller drive. An electric motor of the roller drive can be arranged in said roll 26. The electric motors 6 are regulated by the regulator 22 in said manner.

As Fig. 4 shows, the attached item 2 can also be configured as a sowing machine 70 that in the drawn embodiment in the form of a sowing unit combination comprises a soil cultivation group 80 connected upstream and the outputting device 90 for outputting the grains of the seed. Said output device 90 advantageously comprises metering wheels 100 that can each be driven by electric motors. A suitable regulator 22 regulates the speed of the metering wheels 100 in dependence on relevant operating parameters such as the travel speed, desired output density, that can vary from field section to field section, and the seeds, for example.

Alternatively or additionally to said metering wheels 10, a tire packer unit of the sowing unit combination can also be driven by a tire packer drive having an electric motor. A suitable regulator here regulates the speed of the electric motor of the tire packer drive and thus the speed of the packer wheels, for example in dependence on a desired travel speed that can vary in dependence on ground parameters or on the seeds to be output.

Patentkrav

1. Landbrugsmaskine i form af en læssevogn, der kan monteres på en traktor (1), med
en pickup, som er forsynet med en pigvalse (9) til optagelse af høstmateriale fra jorden, hvor
pigvalsen (9) har et drev (5), som har mindst en elektromotor (6), og
der er tilvejebragt en reguleringsindretning (30), der omfatter en regulator (22), til regulering af drevets (5) omdrejningstal og/eller omdrejningsmoment,
kendetegnet ved, at
elektromotoren (6) er udformet uden rotationsgiver,
reguleringsindretningen (30) har en bestemmelsesindretning (31) til bestemmelse af elektromotorens (6) drejestilling og omdrejningstal ud fra fasepositionen af drejespændingsnettet, der er påtrykt elektromotoren (6), og
regulatoren (22) er indrettet til at øge omdrejningstallet for pigvalsens (9) elektromotor (6), hvis elektromotorens (6) effektoptagelse stiger.

2. Landbrugsmaskine ifølge det foregående krav, hvor bestemmelsesindretningen (31) har bestemmelsesmidler (32) til bestemmelse af de rumlige, magnetiske svingninger i styreværdierne, ud fra hvilke elektromotorens (6) drejestilling kan bestemmes, hvor fortrinsvis de nævnte bestemmelsesmidler (32) har registreringsmidler til registrering af en stigning i mellemkredsstrømmen og/eller en mellemkredsspænding og/eller en aktuel koblingstilstand af en omformer (40), hvorfra svingningerne i styreværdierne så kan bestemmes af bestemmelsesmidlerne (32).

3. Landbrugsmaskine ifølge et af de foregående krav, hvor reguleringsindretningen (30) inklusive bestemmelsesindretningen (31) er udformet som en komponent, som er udformet separat fra elektromotoren (6), og som kan forbindes med elektromotoren (6) ved hjælp af en omformer (40) fra effektelektronikken.

4. Landbrugsmaskine ifølge et af de foregående krav, hvor reguleringsindretningen (30) og/eller bestemmelsesindretningen (31) sammen med en omformer (40) fra effektelektronikken er sammenfattet til en elektronikkomponent,

som på indgangssiden kan påvirkes med en spændingsforsyning og en indstillingsværdi for reguleringsstørrelsen og på udgangssiden stiller strømforsyningen til rådighed for elektromotoren (6).

5. Landbrugsmaskine ifølge et af de foregående krav, som har en transportrotor (10) til transport af det optagne høstmateriale i et høstmaterialelager (11), en skrabebund (200) og/eller en doseringsvalse (12) til aflæsning af høstmaterialet fra høstmaterialelageret (11), hvor transportrotorens (10), skrabebundens (200) og/eller doseringsvalsens (12) drev (5) omfatter en elektromotor (6), der reguleres af regulatoren (22).

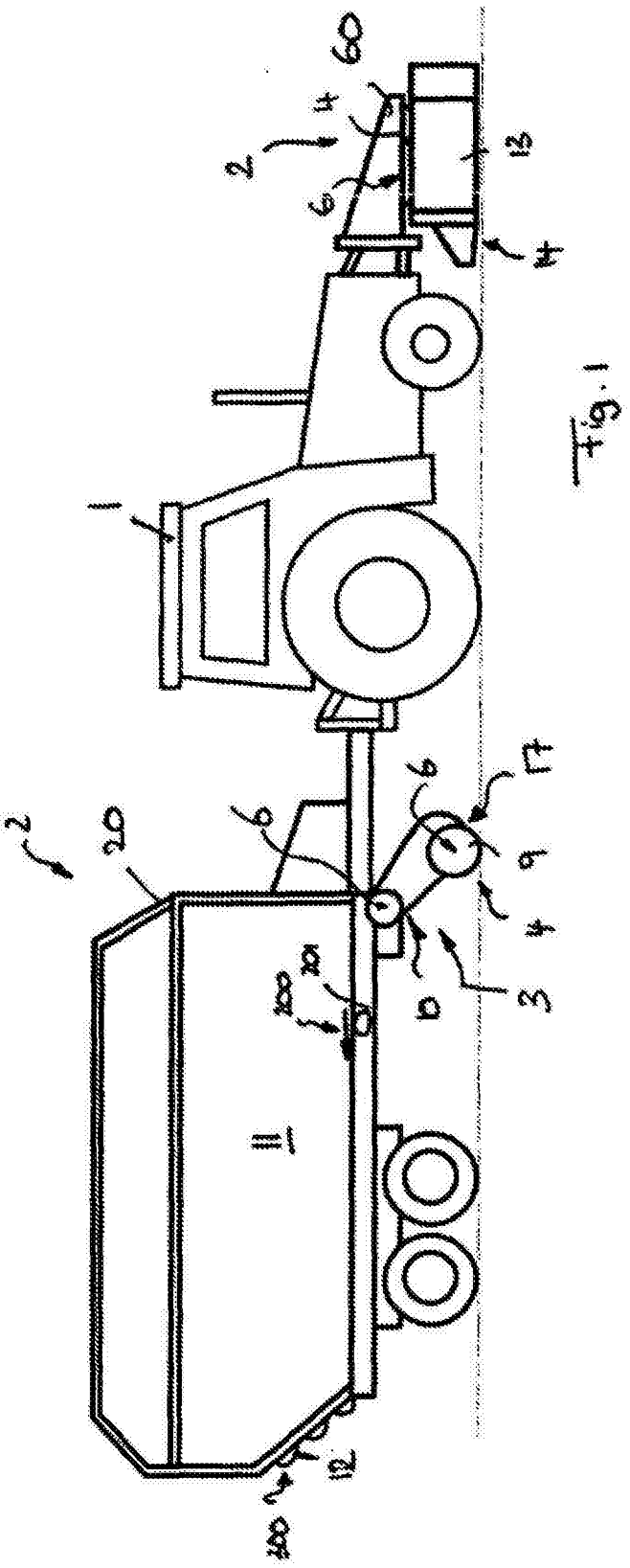

Fig. 1

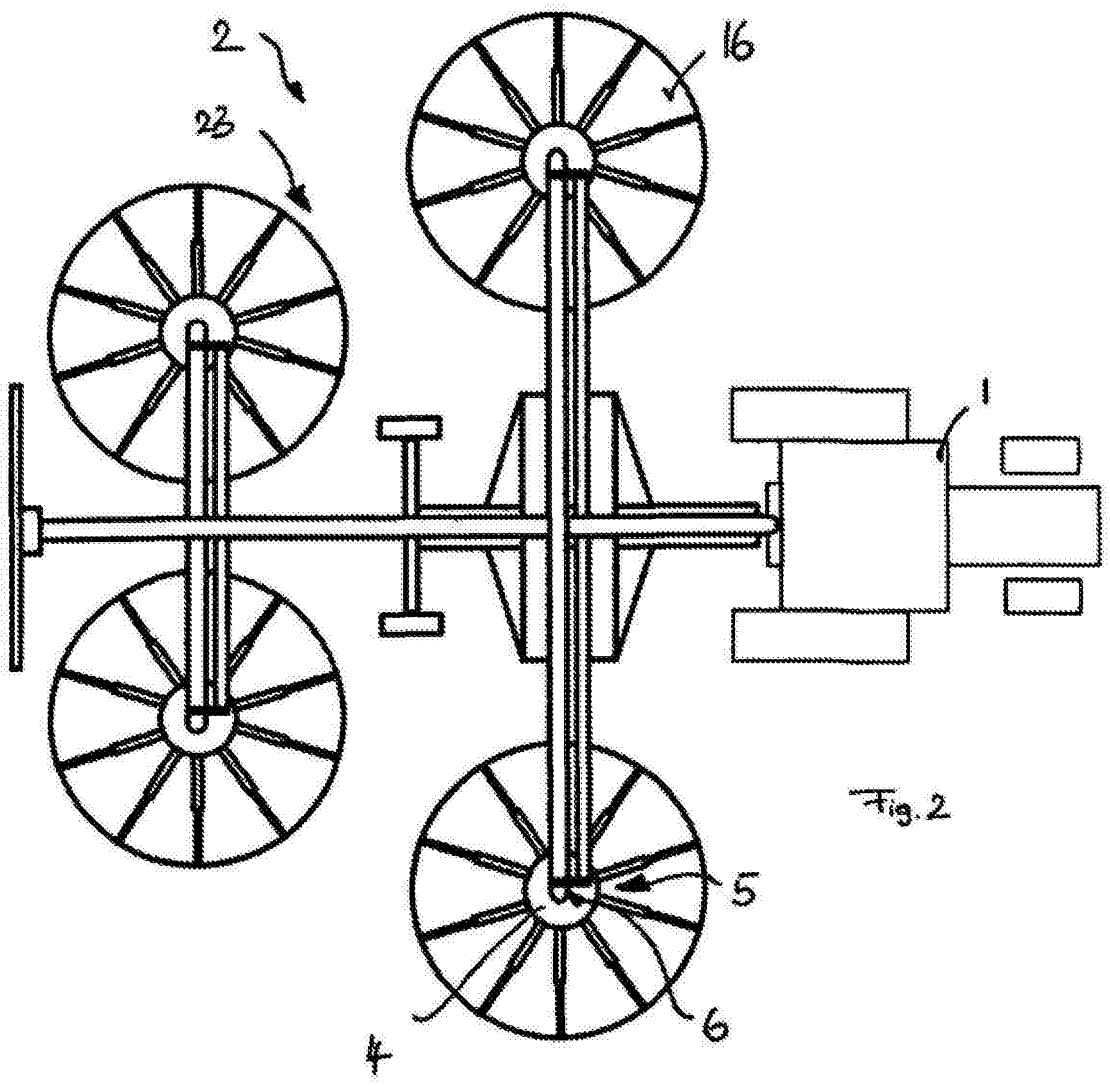

Fig. 2

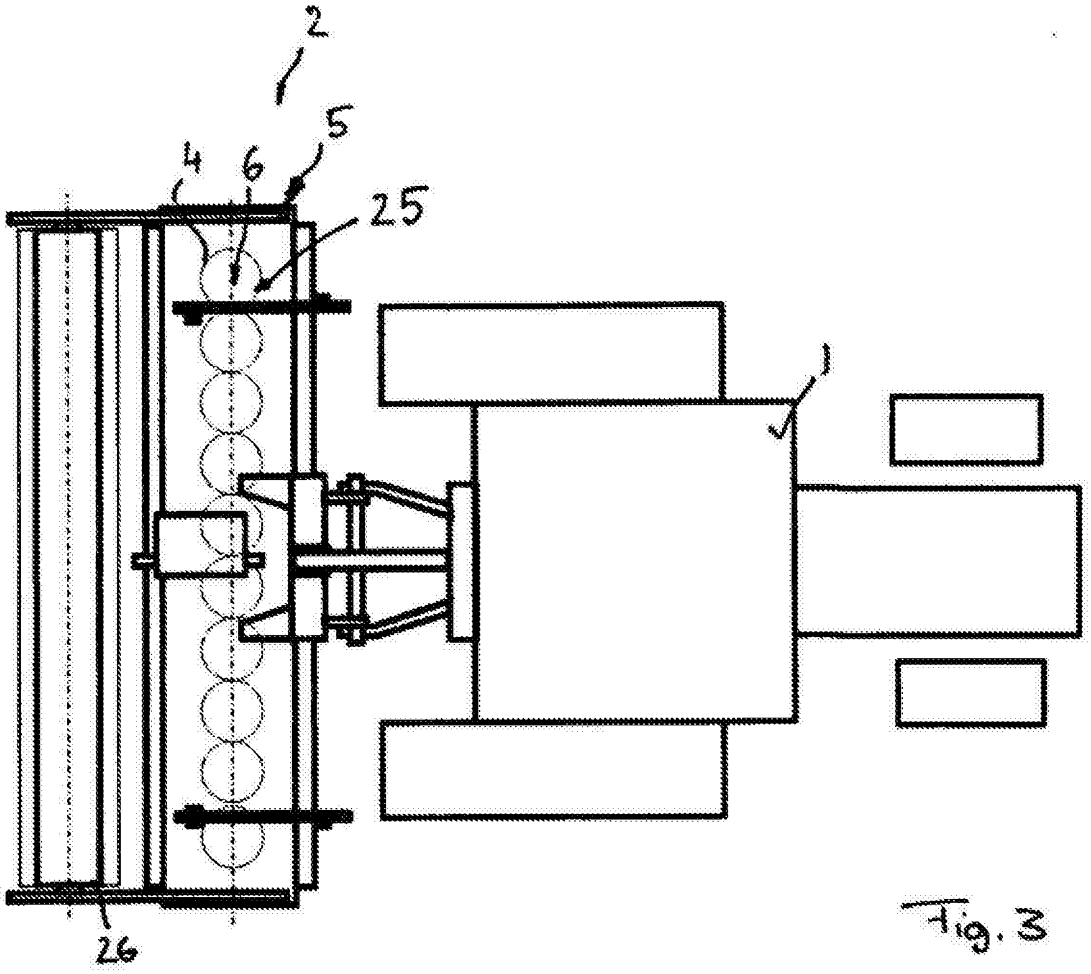

Fig. 3

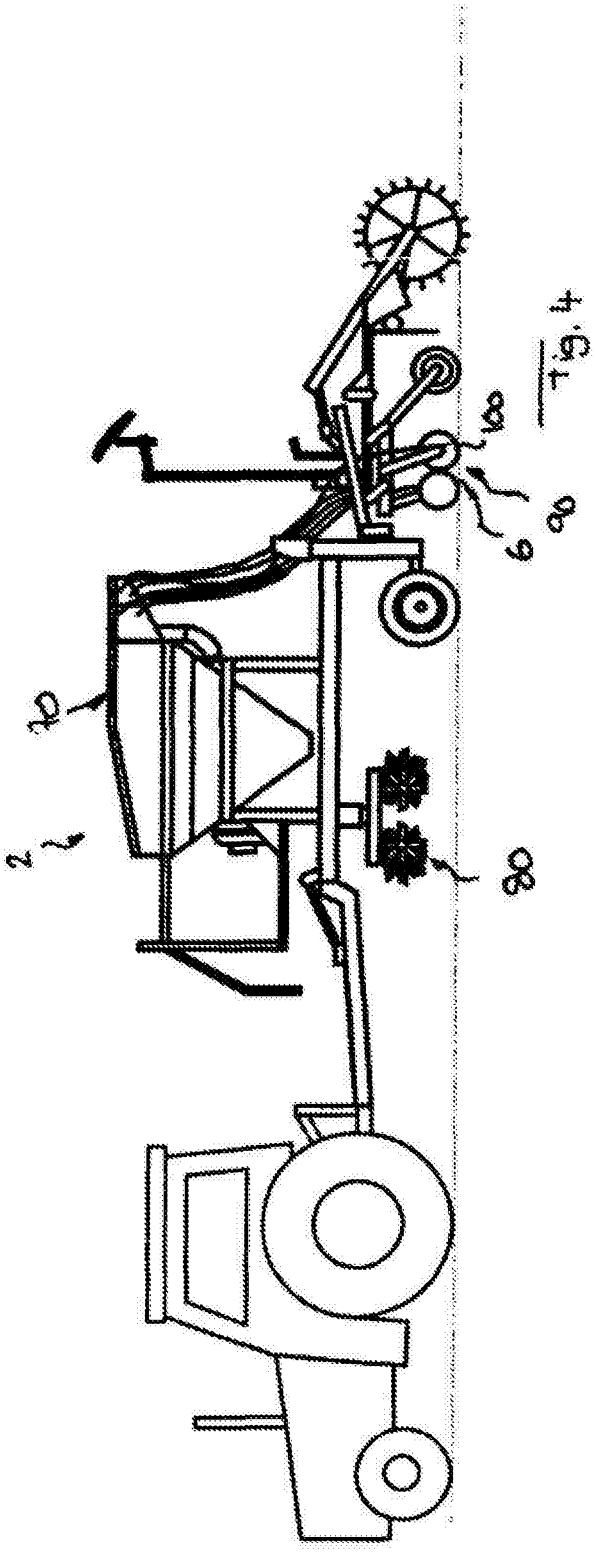
Fig. 4
68
69
66
20
2
80

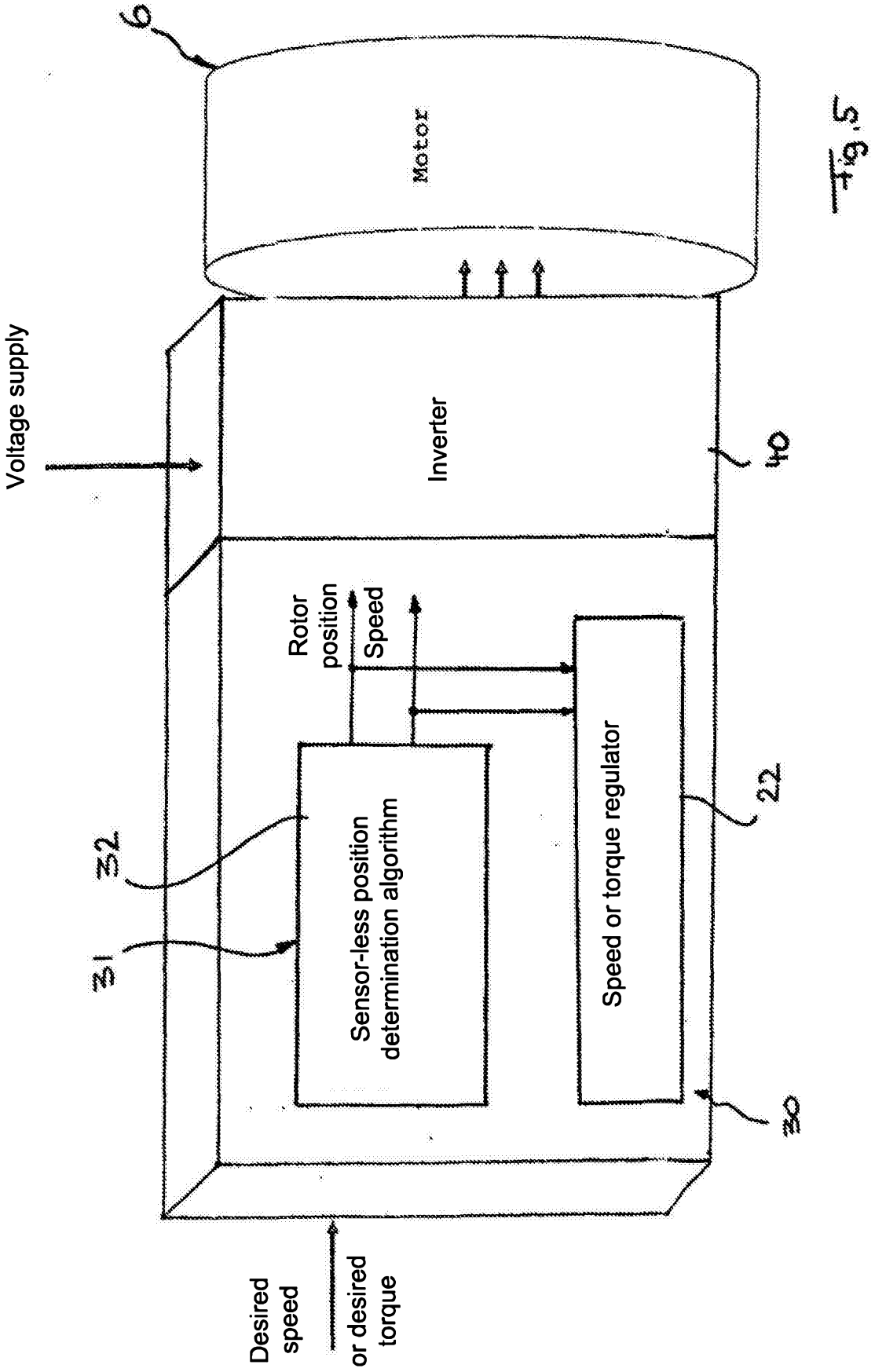
6
Motor
Voltage supply
Inverter
40
Rotor position
Speed
Sensor-less position determination algorithm
Speed or torque regulator
22
32
31
30
Desired speed
or desired torque

Fig. 5