

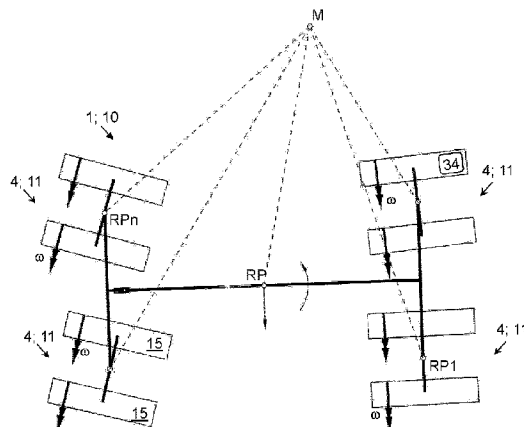


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(54) Titre : PROCÉDE ET DISPOSITIF DE REGLAGE DU DEPLACEMENT D'UN AGENCEMENT DE CHASSIS MOBILE, EN PARTICULIER D'UN SYSTEME DE PONT DE TRANSPORT MOBILE MUNI D'UN CHASSIS A CHENILLES, PAR LE BIAIS DE PLUSIEURS UNITES D'ENTRAINEMENT DONT LA VITESSE PEUT ETRE REGLEE INDIVIDUELLEMENT

(54) Title: METHOD AND DEVICE FOR CONTROLLING THE MOVEMENT OF A MOBILE CHASSIS ASSEMBLY, IN PARTICULAR OF A MOBILE CONVEYOR BRIDGE SYSTEM PROVIDED WITH CRAWLER CHASSIS, VIA MULTIPLE INDIVIDUALLY SPEED-CONTROLLABLE DRIVE UNITS



(57) **Abrégé/Abstract:**

A method is provided for activating and controlling a plurality of chassis/movement systems of at least one mobile crawler system which are mechanically decoupled from one another and are respectively independently pivotable independently about a vertical axis and can be independently oriented and driven. Each chassis/movement system is individually controllable. The chassis/movement systems are controlled in dependence on one another in such a way that at least two of the following individual movement characteristics can be set for specifying the absolute movement of the entire mobile crawler system individually for each chassis/movement system: path of movement, momentary orientation, speed, at least the movement characteristic 'speed' being included. This makes it possible for even very large, bulky items of equipment to be displaced in a way that can be freely individualized. A corresponding crawler system and a control device and a computer program product are also disclosed.



Abstract

A method is provided for activating and controlling a plurality of chassis/movement systems of at least one mobile crawler system which are mechanically decoupled from one another and are respectively independently pivotable independently about a vertical axis and can be independently oriented and driven. Each chassis/movement system is individually controllable. The chassis/movement systems are controlled in dependence on one another in such a way that at least two of the following individual movement characteristics can be set for specifying the absolute movement of the entire mobile crawler system individually for each chassis/movement system: path of movement, momentary orientation, speed, at least the movement characteristic 'speed' being included. This makes it possible for even very large, bulky items of equipment to be displaced in a way that can be freely individualized. A corresponding crawler system and a control device and a computer program product are also disclosed.

**METHOD AND DEVICE FOR CONTROLLING THE MOVEMENT OF A MOBILE
CHASSIS ASSEMBLY, IN PARTICULAR OF A MOBILE CONVEYOR BRIDGE
SYSTEM PROVIDED WITH CRAWLER CHASSIS, VIA MULTIPLE
INDIVIDUALLY SPEED-CONTROLLABLE DRIVE UNITS**

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TECHNICAL FIELD

The invention relates to a method and a device for specifying and controlling the movement of a mobile chassis assembly via multiple individually speed-controllable drive units, in particular of a crawler system with at least three or four crawler chassis or of a
10 mobile conveyor bridge system provided with crawler chassis.

BACKGROUND

Chassis assemblies with multiple drive units for supporting a superstructure on a plurality of individual chassis have to meet high requirements with respect to mechanical stressing and safety-related support of the superstructure. Nevertheless, such assemblies are also
15 intended to be adapted for being moved over rough terrain or at least to be controllable with respect to paths of movement that are variably selectable as freely as possible. In particular, in the area of material flow and materials-handling technology for bulk materials, these requirements involve large dimensions, and so the forces and loads to
20 be managed can become very great. Such assemblies may possibly also have to be moved on an underlying surface that gives way, is mounted in a floating manner or the nature of which varies greatly from place to place. It must also be possible for a movement of the entire assembly to be correspondingly safely and reliably controlled in an open-loop and closed-loop manner and adapted to the situation at the time, even
25 whenever the underlying surface is of a nature that is not foreseeable, for example the underlying surface gives way or an unforeseeable displacement of the assembly in an unplanned direction takes place or is required.

According to some applications, crawlers or double crawlers are used for the chassis.
30 Alternatively, many individual drive units or wheels not in the form of crawlers are used.

Until now, the activation and control of the movement of such chassis were not possible in a particularly flexible way. The path of movement and the variability of the movement were often greatly restricted. For example, US 2015/125252 A1 has disclosed a group of
35 three or more crawlers for transporting heavy loads, wherein the individual crawlers are directly connected to the load being borne or are rotatably and pivotably connected to a

supporting structure for the load. The alignment and movement of the crawlers takes place by means of activation of the chain drive units. In the group, one of the crawlers represents the main crawler. If, for transporting the load, the human operator specifies the speed vector of a linear speed and direction as a travel command at an operator console, then this travel command is transformed for the individual crawlers by the central controller into speed vectors and is transmitted to the controllers of the individual crawlers in the form of corresponding control commands. If the central control detects disturbances, it initiates an immediate stop of all the crawlers.

In the following publication, some of the principles in connection with the control of movements are described:

P. Morin, C. Samson: Motion Control of Wheeled Mobile Robots; INRIA, 06902 Sophia-Antipolis Cedex, France. August 2007; published in: Springer Handbook of Robotics, ISBN 978-3-540-30301-5; 2008.

DESCRIPTION OF THE INVENTION

The object of the invention is to provide a method and a device with the features described at the beginning whereby the freedom of movement and variability, in particular even of very large and bulky chassis assemblies, can be improved, in particular in the case of chassis with crawlers. The object is in particular to allow a system comprising at least two, three, or four chassis that can be oriented independently of one another to be displaced in a flexible and robust way.

This object is achieved according to the invention in particular by a mobile conveyor bridge system adapted for transporting material to be conveyed, having a bridge with a conveyor belt along a main axis of extent, wherein for movement on an underlying surface, the bridge is arranged on a plurality of chassis systems that are respectively pivotable about a vertical axis, furthermore having a spreading system, wherein the material to be conveyed can be transported on the conveyor belt from the bridge onto a discharge device by means of the spreading system, wherein the spreading system is decoupled from the bridge by means of at least one movement system that can be pivoted about a vertical axis for movement on the underlying surface, wherein the spreading system comprises at least two carrier systems, which respectively have at least one movement system in order to move the spreading system on the underlying surface, wherein either each carrier system is arranged on the spreading system in such a way that at least two movement systems laterally enclose the main axis of extent of the bridge, or wherein each carrier system is arranged on the spreading system in such a way that the at least one movement system of the respective carrier system is arranged

on one side in relation to the main axis of extent of the bridge, wherein the mobile conveyor bridge system has an open-loop/closed-loop control device, which is coupled to the chassis systems and the movement systems and is adapted to activate each of the at least three chassis and movement systems individually and to set at least two of the following individual movement characteristics individually and to control them in dependence on one another: path of movement, momentary orientation, speed of the respective chassis/movement system, wherein the chassis systems and/or the movement systems respectively comprise at least one crawler chassis, which is pivotable about a vertical axis and has a plurality of drive units, in particular respectively with at least one double crawler, and wherein the momentary direction of advancement of the respective chassis/movement system and/or the path of movement and/or the speed is specifiable exclusively by specification of the angular speed of individual drive units of the respective chassis/movement system, and wherein the open-loop/closed-loop control device is adapted to prioritize counter-controlling with respect to an individual deviation of at least one setpoint parameter for each chassis/movement system over counter-controlling of a deviation of at least one absolute setpoint parameter of the crawler system. This provides in particular great variability and flexibility with respect to diverse operating situations and movement requirements. It has been found that individual activation and control of the individual even a chassis/movement system also makes it possible to minimize the stresses on the overall structure. Not least, computer-aided control of the overall system can be easily achieved, in particular without the use of on-site personnel (checking the path of movement exclusively "by wire"). In particular, an exclusively kinematically based control concept can be achieved, in particular with reference to individual advancing speeds. In this case, the control may be based in particular on the kinetics of planar, quasi-static movements.

The individual mechanical components of the conveyor bridge system may be designed for example as described in the publication DE 10 2017 216 389 A1. The individual chassis/movement systems may respectively have crawler chassis and together form a multi-crawler chassis system, in particular with crawler pairs and/or double crawler pairs.

The achievement of the open-loop/closed-loop control concept according to the invention is not restricted to conveyor bridge systems. Rather, the invention may also be applied to a large number of different assemblies or items of equipment with multiple individually activatable chassis.

The aforementioned object is accordingly also achieved according to the invention in particular by a mobile crawler system which is arranged on a plurality of chassis and/or movement systems that are respectively pivotable about a vertical axis, wherein each chassis system and each movement system has at least one crawler chassis, in particular with a double crawler, wherein the chassis and movement systems can be oriented independently of one another with respect to their orientation and independently of a superstructure of the crawler system for the definition of a path of movement of the crawler system, wherein the mobile crawler system has an open-loop/closed-loop control device, which is coupled to the chassis systems and the movement systems and is adapted to activate each of the chassis and movement systems individually and to set at least two of the following individual movement characteristics individually and to control them in dependence on one another: path of movement, momentary orientation, speed of the respective chassis/movement system, wherein the chassis systems and/or the movement systems respectively comprise at least one crawler chassis, which is pivotable about a vertical axis and has a plurality of drive units, in particular respectively with at least one double crawler, and wherein the momentary direction of advancement of the respective chassis/movement system and/or the path of movement and/or the speed is specifiable exclusively by specification of the angular speed of individual drive units of the respective chassis/movement system, and wherein the open-loop/closed-loop control device is adapted to prioritize counter-controlling with respect to an individual deviation of at least one setpoint parameter for each chassis/movement system over counter-controlling of a deviation of at least one absolute setpoint parameter of the crawler system.. This produces the aforementioned advantages. In particular, the concept according to the invention can be optionally applied to materials-handling devices or to items of equipment without a materials-handling task. The mobile crawler system has in particular at least three or four movement systems. The mobile crawler system performs for example a materials-handling function in particular for bulk materials, or optionally a purely logistical function.

According to one exemplary embodiment, in total at least four chassis/movement systems are provided. Optionally, at least two chassis systems and at least three or four movement systems are provided.

According to one exemplary embodiment, the chassis systems and/or the movement systems respectively comprise at least one crawler chassis, which is pivotable about a vertical axis and has a plurality of drive units (in particular drive wheels), in particular respectively with at least one double crawler. This allows an application also on rough

terrain or in the case of particularly high loads or in the case of particularly large dimensions.

According to one exemplary embodiment, the path of movement and/or the speed of the
 5 respective chassis/movement system can be controlled exclusively by individual
 activation of individual drive units of the respective chassis/movement system in
 coordination with the further chassis/movement systems, in particular with reference to
 the control parameter 'angular speed'/'rotational speed' of the respective drive unit. This
 not least also makes scalability easily possible.

10 The path of movement of the respective chassis/movement system may for example be
 specifiable exclusively by individual activation of drive units of the chassis/movement
 system, that is to say without steering via a steering axis (in particular without a steering
 crawler, and without any other geometric steering system), in particular by drive steering
 15 (wheel-based steering), in particular by setting different differentiated propulsion at at
 least two drive units of the respective chassis/movement system that are offset in relation
 to one another transversely to the traveling direction. The respective chassis/movement
 system may in this case be mounted and able to be oriented freely rotatably about an at
 least approximately vertically oriented/orientable pivot axis in a torque-free manner
 20 without a steering torque, in particular by controlling the individual advancement of
 individual drive units.

The term drive steering (wheel-based steering) may in this case comprise an operating
 mode by brake steering, optionally also in combination. The term drive steering may
 25 comprise chain or wheel-based steering, in particular so-called skid steering. The term
 drive steering comprises in particular orientation by controlling the differences in traveling
 speed, whether on an individual double crawler or whether with respect to the entire
 assembly.

30 According to one exemplary embodiment, all of the chassis and movement systems are
 mechanically decoupled from one another and as a result can be oriented and can be
 individually driven independently of one another at least about a respective vertical pivot
 axis in relation to one another and in relation to the/a superstructure of the device, in
 particular can be oriented by specifying the type and manner of the drive from a plurality
 35 of drive units (orientation by controlling the advancement). This allows the control to take
 place in particular also independently of the respective design or number of chassis of the
 overall system.

According to one exemplary embodiment, the momentary direction of advancement of the respective chassis/movement system and/or the path of movement and/or the speed is specifiable exclusively by specification/definition of the angular speed/rotational speed of individual drive units (in particular drive wheels) of the respective chassis/movement system. This allows the entire feedback control problem to be focused in particular on the control of a single parameter for the respective drive unit. This also not least makes a lean and reliable method possible.

According to one exemplary embodiment, all of the paths of movement of the mobile conveyor bridge system are specifiable by specification/definition exclusively of angular speeds/rotational speeds of individual drive units (in particular drive wheels) of the respective chassis/movement system, wherein each path of movement is an individual path of movement. As a result, great variability is also ensured along with a lean control concept.

The aforementioned object is achieved according to the invention by a method for activating and controlling a plurality of chassis/movement systems of at least one mobile crawler system, in particular a mobile crawler system in the form of a mobile crawler conveyor system, which are mechanically decoupled from one another and are respectively pivotable independently of one another about a vertical axis and can be oriented and can be driven independently of one another, in particular with a conveyor bridge and/or spreader or tripper car, wherein each chassis/movement system is individually controllable, wherein the chassis/movement systems are controlled in dependence on one another in such a way that at least two of the following individual movement characteristics can be set for specifying the absolute movement of the entire mobile crawler system individually for each chassis/movement system: path of movement, momentary orientation, momentary speed state, at least the momentary speed state being included. This produces the aforementioned advantages. In particular, the feedback control problem can be reduced to just a few or only a single characteristic. This not least also makes a still manageable complexity possible.

The absolute movement of the entire mobile crawler system may in this case also be defined for example by two different speed parameters: angular speed, (linear) straight-ahead speed. The respective movement characteristic may in this case also be defined vectorially with reference to at least two spatial axes, in particular with reference to all three spatial axes.

According to the invention, at least the speed of the respective chassis/movement system is controlled exclusively by individual activation of individual drive units of the respective chassis/movement system in coordination with the further chassis/movement systems
 5 with exclusive reference to the individual control parameter of the 'angular speed'/'rotational speed' for each drive unit.

Furthermore, according to the invention, the counter-controlling with respect to an individual deviation of at least one setpoint parameter for each chassis/movement system
 10 is prioritized over counter-controlling of a deviation of at least one absolute setpoint parameter of the entire crawler system. By this, in particular also a particularly reactive, time-efficient type of control can be ensured.

It has been found that, on the basis of a consideration of individual axes, a control
 15 concept for the overall system can be arrived at in an elegant way. In particular, initially assuming non-holonomic kinematic constraints for the respective chassis/movement system, on the one hand, the momentary path of movement can be determined, and on the other hand, the momentary speed vector at at least one reference point can also be determined. Control or automation of the sequence of movements for the overall system
 20 can in this case also be described with reference to the publication by P. Morin et al. In particular, control for a two-wheeled robot can be applied to the control of a respective chassis/movement system and more specifically also to the control of a respective drive unit. The approaches described in the publication by P. Morin et al. can be implemented in particular as a control level in a plurality of control levels of the control concept
 25 according to the invention. By contrast with the approach described in the publication by P. Morin et al., the present invention is also based on the concept of ensuring a higher-level control of the overall system by providing that one or more variables (in comparison with the coefficients mentioned in the aforementioned publication by P. Morin, in particular k_2 , k_3), are not considered as constants but as functions, in particular as
 30 functions of the accumulated angular deviation of individual chassis from the orientations of individual chassis intended at the respective point in time, in particular with prioritization of deviations in the orientation of the individual chassis in comparison with deviations of the orientation of the overall system. Consequently, on the basis of a control concept described in the publication by P. Morin, by splitting the feedback control problem
 35 into individual sub-problems, an extended control concept can be provided even for a comparatively complex overall system, in particular largely independently of the number of chassis or drive units. The control concept according to the invention is easily scalable.

According to one embodiment, the chassis/movement systems are controlled in dependence on one another, in that exclusively the following individual speed movement characteristics are set: angular speed (rotational speed), (linear) straight-ahead speed (translational speed). By reference exclusively to the speed and by differentiation with respect to rotational and translational speeds, a robust concept can also be provided.

According to one embodiment, the chassis/movement systems are controlled in dependence on one another, in that at least one of the following individual movement characteristics are deductively determined by integration over time from the movement characteristic 'speed': path of movement, momentary orientation. This allows the feedback control problem also to be focused on the one (single) movement characteristic 'speed'.

According to one embodiment, the control is applied with respect to at least one of the following control systematics (control loops) respectively as an individual feedback control problem for each chassis/movement system:

- first feedback control problem: path-of-movement specification by reference to a reference configuration, in particular a time-variable reference configuration;
- second feedback control problem: path-of-movement specification by reference to a setpoint path of movement of the entire mobile crawler system, in particular for a predefined speed, in particular predefined tangential speed.

This allows the control also to be adapted to a specific operating situation, in particular to be weighted with respect to priority control criteria (for example advancement speed or positional accuracy or minimized structural loads or stresses). The feedback control problems may also be processed in combination with one another. The specification of the path of movement may also take place in dependence on the solving of the two feedback control problems.

The time-variable reference configuration may be predefined for example in dependence on a loading that is variable in terms of materials-handling (bulk material) or load distribution of the system, for example for the avoidance of a lateral inclination of the system beyond a maximum threshold value.

The reference configuration may comprise for example a specification of relative orientation and distances of the chassis in relation to the overall system (reference point or reference frame) and/or in relation to one another.

- 5 The reference configuration describes in particular the attitude (position and/or orientation) intended at the respective point in time and also the speed state (translational and rotational) intended at the respective point in time of the higher-level overall system. The individual attitude and the individual speed state of individual chassis can be determined from this. The description of the attitude and the description of the individual speed state
10 of individual chassis are therefore not included by the reference configuration.

- Control systematics is to be understood here also in the sense of a control ranking or a flowchart or a control concept, which may optionally also include multiple feedback control problems, in particular with hierarchical weighting with respect to one another. The
15 control systematics may in particular run in a fully automated manner without human intervention. The control requires no manual intervention.

- Control along the setpoint path of movement may in this case take place for example by specification or by adjustment of individual orientation of the crawler chassis in
20 dependence on a tangential speed referred to the path of movement, in particular in the case of a curved path of movement.

- According to one embodiment, the control (control loop, in particular in real time) takes place according to at least one of the feedback control problems in the following
25 sequence:
- definition of at least one error for the movement or for the absolute setpoint path of movement of the crawler system;
 - determining the momentary speed state of the crawler system;
 - determining the momentary individual paths of movement and individual speeds, in
30 particular with reference to individual radii of curvature of the individual momentary paths of movement of a respective chassis/movement system;
 - applying at least one control law, in particular the control law for single-axis chassis/movement systems, to the momentary individual movements/paths of movement with reference to the momentary absolute speed, for controlling the momentary individual
35 paths of movement.

This also allows great accuracy to be achieved, in particular also in the manner of a plausibility check with respect to the plurality of individual chassis/movement systems. This control concept also has the advantage that an entire feedback control problem can be deductively concluded from comparatively simple, compact individual feedback control problems (in particular with respect to individual drive units). To put it another way: the open-loop/closed-loop control device is adapted to specify the momentary individual paths of movement by applying at least one control law to the momentary individual paths of movement of the respective chassis while taking into account the momentary absolute speed, in particular in that only one drive unit for each crawler (if applicable, only two drive units for each double crawler) is/are controlled with respect to its/their advancing speed.

On the basis of control of a single-axis driving device, it is possible here to make a generalization for multi-axis driving devices with a plurality of chassis mounted independently of one another.

An error is to be understood here for example in the sense of a deviation of a movement characteristic or else a stress characteristic or load characteristic (force, moment, oscillation, mechanical stress) greater than a maximum threshold value. The threshold value may be individually predefined. The error may relate here for example to a locational, temporal, or other variable.

Location and speed sensors, which can be individually implemented, may be used in particular for determining momentary speeds and paths of movement. The radii of curvature of the respective path of movement may in this case correspond to the radii between an individual reference point and the instantaneous center of rotation.

Control laws according to chapter 34.4.3 ("path following with orientation control") of the aforementioned publication by P. Morin et al., may be used in particular as the control law for single-axis chassis/movement systems, in particular by taking into account the generalization made, in particular in that coefficients k_i are defined as functions of the accumulated angular deviation of individual chassis.

According to one embodiment, the control takes place individually with respect to individual drive units (in particular drive wheels) of the chassis systems and/or the movement systems, in particular with the chassis/movement systems respectively in the form of the crawler chassis. This also allows local loads to be minimized. Each

chassis/movement system may for example initially be positioned as a priority optimally with respect to supporting the superstructure.

According to one embodiment, at least four chassis/movement systems are individually
 5 activated and controlled in dependence on one another, in particular at least with respect to the individual control parameter 'momentary angular speed'/'rotational speed' for each drive unit (in particular drive wheel).

Optionally, at least eight drive units (in particular drive wheels) of at least four
 10 chassis/movement systems are individually activated singly (at least eight control variables of one parameter) or in pairs (at least four control variables of one parameter) and controlled in dependence on one another, in particular at least with respect to the individual control parameter 'momentary angular speed'/'rotational speed' for each drive unit (in particular drive wheel).

15 Optionally, at least sixteen drive units (in particular drive wheels) of at least four chassis/movement systems are individually activated singly (at least sixteen control variables of one parameter) or in pairs (at least eight control variables of one parameter) and controlled in dependence on one another, in particular at least with respect to the
 20 individual control parameter 'momentary angular speed'/'rotational speed' for each drive unit (in particular drive wheel).

According to one embodiment, exclusively the angular speeds/rotational speeds of individual drive units (in particular drive wheels) of the respective chassis/movement
 25 system are controlled as the control parameter, in particular in dependence on one another, in particular for controlling a momentary direction of advancement and/or the path of movement and/or the speed (momentary speed state).

According to one embodiment, an individual reference point with reference to which the
 30 control takes place is defined for each chassis/movement system, in particular a reference point at least approximately corresponding to the vertical axis of rotation of the respective chassis/movement system. In this case, an absolute reference point with reference to which the control takes place may also be defined for the mobile conveyor bridge system, in particular a reference point in an arrangement at least approximately
 35 midway with reference to the longitudinal and/or transverse extent of the bridge or with reference to the longitudinal and/or transverse extent of the spreading system. Optionally,

a reference point, which is arranged at least approximately midway on an axis, which connects two drive units in opposite crawlers of a double crawler, may also be defined.

According to one embodiment, the control takes place with reference to a single common
 5 setpoint instantaneous center of rotation for all of the chassis/movement systems and for the entire crawler system. This also makes it possible for the individual feedback control problems to be reduced to one entire feedback control problem for the overall system. In this case, all of the chassis/movement systems may be activated in such a way that a deviation of individual instantaneous centers of rotation from a common setpoint
 10 instantaneous center of rotation is counter-controlled, and so their path of movement is respectively adjusted about the same single instantaneous center of rotation.

In this case, the attitude of the common instantaneous center of rotation or the position of the setpoint instantaneous center of rotation may optionally be adapted computationally
 15 with reference to the kinetics occurring during skidding, in particular since the attitude of the momentary instantaneous center of rotation occurring may deviate from the attitude of a setpoint instantaneous center of rotation that is/has been determined primarily or exclusively on the basis of kinematics of rolling (non-holonomic constraints).

20 According to one embodiment, a speed of the mobile crawler or conveyor bridge system is not taken into account in the control. Independently of the absolute speed of the overall system, the intended setpoint speed/angular speed of the overall system can be adjusted at the respective point in time.

25 In the control, the orientation of a/the bridge and/or of a/the spreading system can be taken into account, in particular in relation to one another, in particular in that a relative distance and/or a relative angle in relation to one another is taken into account, and so a synchronization of the control of at least two systems that are moved in relation to one another is ensured. This may take place for example by determining errors, which are
 30 counter-controlled (stabilization around zero). If for example the setpoint distance of two reference points is intended to be one meter, but the actual distance measured at the time is 1.1 meters, forming the difference (setpoint – actual) gives a (vector-valued) error, from which subsequently (at the respective point in time/momentarily) a speed state that reduces this error (and stabilizes around zero) is calculated.

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The control may rely on predefined characterizing variables, in particular at least one geometry characteristic for a/the bridge and/or for a/the spreading system and/or for the respective chassis/movement system.

- 5 According to one embodiment, the control involves detection of an individual mechanical load (structural stressing) of each chassis/movement system, in particular load in a tangential and/or normal direction with respect to the respective chassis/movement system. This also allows individual control to take place, with respect to the requirement of “minimized structural load” in each case locally with respect to the respective
- 10 chassis/movement system. In this case, mechanical stressing, in particular of a/the crawler system, that is caused by the movement of the individual chassis/movement systems can be detected and counter-controlled by specification of advancing speeds of individual drive units.
- 15 According to one embodiment, by the method can, a mobile conveyor bridge system adapted for transporting material to be conveyed is activated and controlled, having a bridge with a conveyor belt along a main axis of extent, wherein for movement on an underlying surface, the bridge is arranged on a plurality of chassis systems that are respectively pivotable about a vertical axis, also having a spreading system, wherein the
- 20 material to be conveyed can be transported on the conveyor belt from the bridge onto a discharge device by the spreading system, wherein for movement on the underlying surface, the spreading system is decoupled from the bridge by at least one movement system that can be pivoted about a vertical axis for movement on the underlying surface, wherein the spreading system comprises at least two carrier systems, which respectively
- 25 have at least one movement system in order to move the spreading system on the underlying surface, wherein either each carrier system is arranged on the spreading system in such a way that at least two movement systems laterally enclose the main axis of extent of the bridge, or wherein each carrier system is arranged on the spreading system in such a way that the at least one movement system of the respective carrier
- 30 system is arranged on one side in relation to the main axis of extent of the bridge, wherein each of the chassis and movement systems is individually activated and controlled with respect to a path of movement and/or a momentary orientation and/or a speed of the respective chassis/movement system both, individually and in dependence on one another.

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According to one embodiment, the control takes place while taking into account measured values of force and/or of moment and/or of stress, in particular detected by at

least one structural-load sensor (for example strain-measuring sensor system on the superstructure) in such a way that the elastic energy of the structure or the structural load is minimized.

- 5 According to one embodiment, the control is also performed with reference to at least one relative distance parameter between the points of rotation (vertical axes of rotation) of the individual chassis/movement systems or with reference to a tolerance range for this distance, in particular as a plausibility check, in particular in alignment with measured values from force and/or moment and/or stress measurements. The control in
10 dependence on distance values may make a deductive analysis of stress and load states possible, in particular even in the case of assemblies of very large dimensions.

- The aforementioned object is also achieved according to the invention in particular by an open-loop/closed-loop control device adapted for performing a previously described
15 method, wherein the open-loop/closed-loop control device is set up for individual control of each chassis/movement system by individual activation and control of individual drive units (in particular drive wheels) of the respective chassis/movement system, in particular with respect to the momentary angular speed/rotational speed of the respective drive unit, in particular in dependence on the other chassis/movement systems respectively. This
20 produces the aforementioned advantages.

- The aforementioned object is also achieved according to the invention in particular by use of an open-loop/closed-loop control device for performing the aforementioned method for individually activating and controlling at least three or four chassis/movement systems,
25 both, the chassis/movement systems of a conveyor bridge and the chassis/movement systems of a mobile crawler system, in a combined system comprising at least one mobile conveyor bridge system with at least one spreading system decoupled therefrom. This produces the aforementioned advantages.

- 30 The aforementioned object is also achieved according to the invention in particular by use of an open-loop/closed-loop control device for performing a method for activating and controlling a plurality of crawler chassis of chassis/movement systems of a crawler system, in particular for individually activating and controlling at least three or four chassis/movement systems, in the previously described method, wherein the open-
35 loop/closed-loop control device is used for specifying individual rotational and translational speeds of the individual crawler chassis. This produces the aforementioned advantages.

The aforementioned object is also achieved according to the invention in particular by a computer program product set up for performing a previously described method when the method is performed on a computer.

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The aforementioned object is also achieved according to the invention in particular by a computer program product set up for controlling the aforementioned method for activating and controlling a plurality of chassis/movement systems of a conveyor bridge and/or a plurality of chassis/movement systems of a mobile crawler system, in particular for
10 individually activating and controlling at least three or four chassis/movement systems, in particular both, the chassis/movement systems of the conveyor bridge and the chassis/movement system of the spreading system, in a combined system comprising at least one mobile conveyor bridge system with at least one spreading system decoupled therefrom, wherein the computer program product is adapted for individually activating a
15 respective drive unit of the respective chassis/movement system and is also adapted for controlling the advancing speed of the respective drive unit in dependence on a specification of the path of movement by reference to a time-variable reference configuration (first feedback control problem) and/or in dependence on a specification of the path of movement by reference to a setpoint path of movement of the conveyor bridge
20 or of the spreading system (second feedback control problem) when the method is performed on a computer. This in each case produces the aforementioned advantages.

The aforementioned object is also achieved according to the invention in particular by a computer program product adapted for controlling a method for activating and controlling
25 a plurality of crawler chassis of chassis/movement systems of a crawler system, in particular for individually activating and controlling at least three or four chassis/movement systems, in the previously described method, wherein individual rotational and translational setpoint speeds of the individual crawler chassis are specified for the control when the method is performed on a computer. This produces the
30 aforementioned advantages.

DESCRIPTION OF THE FIGURES

Further features and advantages of the invention are apparent from the description of at least one exemplary embodiment with reference to drawings, and from the drawings
35 themselves, in which

Fig. 1A, 1B respectively show in a schematic representation in side view a mobile crawler system according to one exemplary embodiment or according to one application;

5 Fig. 2 shows in a schematic representation in side view a mobile conveyor bridge system according to one exemplary embodiment or according to a further application;

10 Fig. 3, 4, 5 respectively show in a plan view individual movement states and relative arrangements of individual chassis during the controlling of a crawler or conveyor bridge system according to one exemplary embodiment;

15 Fig. 6 shows in a perspective side view in a schematic representation a system with four chassis, which are respectively measured and controlled at a reference point with respect to the applied force effect according to one exemplary embodiment.

For reference signs not described explicitly with respect to a single figure, reference is made to the other figures.

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For the purpose of easier understanding, the figures are partly described together with reference to all the reference signs. Details or special features shown in the respective figures are described individually.

25 DETAILED DESCRIPTION OF THE FIGURES

Fig. 1A, 1B show a mobile crawler system 10 with a superstructure 5, which is mounted on four chassis/movement systems 4, 11, which respectively have a crawler chassis 15 with two crawlers (double crawler chassis). Each crawler is driven by multiple drive units 14; two drive wheels are respectively represented here, while it is also possible for more than two drive wheels to be provided. Each chassis/movement system 4, 11 is pivotable about an at least approximately vertically oriented pivot axis z1. The pivot axis z1 is oriented in particular orthogonally in relation to a traveling direction of the overall system 10.

35 Fig. 2 shows a mobile conveyor bridge system 1 for transporting material to be conveyed, with a bridge with a conveyor belt. The bridge 2 has a plurality of chassis systems 4, designed as double crawler chassis, for movement on an underlying surface 6. The

double crawler chassis have at least two drive units (in particular drive wheels) on each side.

The material to be conveyed (not shown) can be transported on the conveyor belt 3 from the bridge 2 onto a discharge device 8 by a spreading system 7. The conveyor belt 3 is guided on conveyor rollers. For the movement on the underlying surface 6, the spreading system 7 has in the present exemplary embodiment four movement systems 11, designed as double crawler chassis. For example, the double crawler chassis are supported in a four-point supporting arrangement.

Double crawler chassis have the advantage that they are respectively pivotable about an axis that is vertical in relation to the underlying surface 6, whereby the mobility of the spreading system 7 is ultimately increased. In the present exemplary embodiment, the double crawler chassis are respectively designed without a steering crawler or any other steering device. To put it another way: the double crawler chassis orient themselves by a difference in the propulsion on the respective side or on the respective crawler. The double crawler chassis have at least two drive units 14 (in particular drive wheels) on each side. These may be individually activatable/controllable singly, individually or in pairs.

In the case of this design of the movement systems, the spreading system 7 is substantially statically decoupled/decouplable from the bridge 2. Substantially means here that, at least via the conveyor belt 3, a physical connection between the spreading system 7 and the bridge 2 does exist. Furthermore, cables may run between the spreading system 7 and the bridge 2. However, no load transfer of the dead weight of the spreading system 7 to the bridge 2 takes place. Preferably, at least 90% of the weight load of the spreading system 7 bears directly on the underlying surface 6 via the double crawler chassis. The spreading system 7 mechanically bears on the underlying surface 6 exclusively via the double crawler chassis.

The spreading system 7 comprises for example two carrier systems 9. The carrier systems 9 are for example formed in a u-shaped manner with in each case a horizontal bar and two vertical supports 92. The carrier systems 9 may be formed in the form of a portal.

The carrier systems 9 may for example respectively have two movement systems 11 formed as double crawler chassis, in order to move the spreading system 7 on the underlying surface 6.

5 For example, each carrier system 9 is arranged on the mobile conveyor bridge system 1 in such a way that the two double crawler chassis of the carrier system 9 in each case laterally enclose the main axis of extent of the bridge 2. Optionally, each carrier system 9 is arranged on the mobile conveyor bridge system 1 in such a way that a respective movement system 11 is arranged on one side next to the main axis of extent of the bridge
10 2. The carrier system 9 may be adjustable in height by lifting means (for example compensating cylinders). Leveling cylinders may be arranged between the bridge 2 and the chassis systems 4, in order for example to compensate for gradients of the underlying surface 6. The conveyor belt 3 is guided from the bridge 2 to the spreading system 7 by way of a conveyor belt receiver 12 arranged on the spreading system 7. The conveyor
15 belt receiver 12 has for example lifting means and/or pivoting means. The spreading system 7 is formed in particular as a tripper car.

The chassis systems 4 of the bridge 2 are formed as double crawler chassis, which here are arranged pivoted at right angles in relation to the movement systems of the spreading
20 system 7 formed as double crawler chassis. This relative arrangement is variable.

An open-loop/closed-loop control device 20 is in connection with a respective drive unit 14 and is adapted to individually activate and control the respective drive unit, in particular in dependence on or as a function of at least one measured value detected
25 individually or with reference to the overall system or with relative reference to a further overall system.

The overall system 1, 10 may respectively have a measuring sensor system 30, which may comprise sensors adapted to the application, in particular force sensors 31, speed
30 sensors (absolute speed) 32, angular speed sensors (individual speed) 33, direction sensors 34. The number and arrangement of the sensors may be individualized according to the application.

Fig. 3 shows a system 1; 10, which is made up of four chassis 4; 11 and is moved about
35 an instantaneous center of rotation M. A reference point RP is defined for the overall system, in particular in a midway arrangement, and individual reference points RP1, RPn are defined for each of the chassis 4; 11, in particular in a position on the vertical pivot

axis of the respective chassis. The vectors indicated at the absolute reference point RP identify the applied force effect and/or movement states.

Fig. 3 also illustrates the relationship between the individual (propulsion-) speed and orientation of the chassis, in particular since all chassis are designed without a steering crawler or any other geometric steering systems (in particular drive steering or wheel-based steering). A single rotational speed vector ω is shown for each crawler 15, in order to illustrate that a single individual speed parameter for each crawler may be sufficient for the control.

Generally, the following can be stated with respect to the control concept of the present invention: the individual orientation of the chassis or crawlers on the one hand and the achievement of the movement of the overall system on the other hand do not have to take place sequentially, but rather the control process can be achieved continuously-parallel. To put it another way: both, the orientation of individual chassis and the movement of the higher-level overall system, can be controlled at the same time.

In Fig. 4, the radius of the path of movement of the overall system is much smaller than that in Fig. 3. This may be accomplished for example by the further outer-lying crawler 15 (on the left in the traveling direction) of the front pair of crawlers exerting a greater advancement than the further inner-lying crawler (in the case of the rear pairs of crawlers, they are oppositely controlled).

In Fig. 5, a setpoint-actual comparison is illustrated. The four chassis and their individual reference points RP_n respectively move on a momentary individual path of movement C^n (dashed line), but are intended to move on a respective individual setpoint path of movement (dotted line) C_n . The reference to the overall system can take place correspondingly, wherein in particular a distinction can be made between two different setpoint paths of movement:

- setpoint path of movement C^0 is the setpoint path that is determined without taking into account the mechanical stress;
- setpoint path of movement C is the setpoint path "corrected" for the purpose of reducing the mechanical stress, that is to say the path of movement optimized in terms of control.

The respective path of movement is defined for example by the respective radius r^n , r , between the instantaneous center of rotation M and the reference point RP, RP_n .

In Fig. 6, the individual force vectors **F1**, **F2**, **F3** in the respective spatial directions are respectively illustrated with reference to one of the individual reference points. As previously mentioned, the state of stress can be detected by the measuring sensor system 30, 31, 34 and taken into account in the control.

List of reference signs

1	Mobile conveyor bridge system
2	Bridge
3	Conveyor belt
4	Chassis system
5	Superstructure
6	Underlying surface
7	Spreading system
8	Discharge device
9	Carrier system
92	Vertical support
10	Mobile crawler system
11	Movement system
12	Conveyor belt receiver
14	Drive unit
15	Crawler chassis
20	Open-loop/closed-loop control device
30	Measuring sensor system
31	Force sensor
32	Speed sensor (absolute speed)
33	Angular speed sensor (individual speed)
34	Direction sensor
C^0	Momentary path of movement of overall system
C	Setpoint path of movement of overall system
C^{0n}	Individual momentary path of movement
C_n	Individual setpoint path of movement
F1	Force vector in first spatial direction
F2	Force vector in second spatial direction
F3	Force vector in third spatial direction
M	Instantaneous center of rotation
r^{0n}	Momentary individual radius

r_n	Individual setpoint radius
r^0	Momentary radius of overall system
r	Setpoint radius of overall system
RP	Reference point of overall system
RP1	First individual reference point
RPn	Further individual reference point
ω	Individual angular speed vector (small omega)
z_1	Pivot axis

Claims

1. A method for activating and controlling a plurality of chassis/movement systems of at least one mobile crawler system which are mechanically decoupled from one another and are respectively pivotable independently of one another about a vertical axis and can be oriented and can be driven independently of one another, wherein each chassis/movement system is individually controllable and the chassis/movement systems are controlled in dependence on one another in such a way that at least two of the following individual movement characteristics can be set for specifying absolute movement of the mobile crawler system individually for each chassis/movement system: path of movement, momentary orientation, momentary speed state, at least the momentary speed state being included, wherein at least a speed of a respective chassis/movement system is controlled exclusively by individual activation of individual drive units of the respective chassis/movement system in coordination with further chassis/movement systems with exclusive reference to an individual control parameter angular speed/rotational speed for each drive unit, wherein counter-controlling with respect to an individual deviation of at least one setpoint parameter for each chassis/movement system is prioritized over counter-controlling of a deviation of at least one absolute setpoint parameter of the mobile crawler system.
2. The method according to claim 1, wherein the chassis/movement systems are controlled in dependence on one another, in that at least one of the following individual movement characteristics are deductively determined by integration over time from a movement characteristic speed: path of movement, momentary orientation.
3. The method according to any one of claims 1 and 2, wherein control is applied with respect to at least one of the following control systematics respectively as an individual feedback control problem for each chassis/movement system:
 - first feedback control problem: path-of-movement specification by reference to a time-variable reference configuration;
 - second feedback control problem: path-of-movement specification by reference to a setpoint path of movement of the mobile crawler system for a predefined speed.
4. The method according to claim 3, wherein the control takes place according to at least one of the feedback control problems in the following sequence:

- definition of at least one error for movement of the mobile crawler system;
- determining the momentary speed state of the mobile crawler system;
- determining momentary individual paths of movement and individual speeds with reference to individual radii of curvature of the momentary individual paths of movement of a respective chassis/movement system;
- applying at least one control law for single-axis chassis/movement systems, to the momentary individual paths of movement with reference to momentary absolute speed, for controlling the momentary individual paths of movement.

5. The method according to any one of claims 3 to 4, wherein the control takes place with reference to a single common setpoint instantaneous center of rotation for all of the chassis/movement systems and for the mobile crawler system.

6. The method according to any one of claims 3 to 5, wherein during the control, at least one of:

an individual mechanical load of each chassis/movement system in at least one of a tangential and a normal direction with respect to the respective chassis/movement system is detected; and

mechanical stressing that is caused by movement of the individual chassis/movement systems is detected and counter-controlled by specification of advancing speeds of individual drive units.

7. The method according to any one of claims 3 to 6, wherein the control takes place while taking into account at least one of measured values of force, of moment, and of stress.

8. The method according to claim 7, wherein the at least one of measured values of force, of moment, and of stress are detected by at least one structural-load sensor in such a way that elastic energy of a structure or a structural load is minimized.

9. The method according to any one of claims 3 to 8, wherein the control is also performed with reference to at least one relative distance parameter between points of rotation of individual chassis/movement systems or with reference to a tolerance range for this distance as a plausibility check.

10. The method according to claim 9, wherein the control is also performed in alignment with measured values from at least one of force, moment and stress measurements.

11. The method according to any one of claims 3 to 10, wherein the control takes place in a fully automated manner.

12. The use of an open-loop/closed-loop control device for performing the method according to any one of claims 1 to 11 for individually activating and controlling at least three or four chassis/movement systems, both, the chassis/movement systems of a conveyor bridge and the chassis/movement systems of a mobile crawler system in a combined system consisting of at least one mobile conveyor bridge system and at least one spreading system decoupled therefrom.

13. A computer readable medium having stored thereon statements and instructions that when executed by a processor cause the processor to execute the method according to any one of claims 1 to 11 for activating and controlling at least one of a plurality of chassis/movement systems of a conveyor bridge and a plurality of chassis/movement systems of a mobile crawler system in a combined system consisting of at least one mobile conveyor bridge system and at least one spreading system decoupled therefrom, wherein the statements and instructions when executed by the processor individually activate a respective drive unit of the respective chassis/movement system and control an advancing speed of the respective drive unit at least one of in dependence on a specification of the path of movement by reference to a time-variable reference configuration and in dependence on a specification of the path of movement by reference to a setpoint path of movement of the conveyor bridge or of a spreading system.

14. A mobile crawler system, which is arranged on at least one of a plurality of chassis systems and movement systems that are respectively pivotable about a vertical axis, wherein each chassis system and each movement system has at least one crawler chassis, wherein the chassis systems and movement systems can be oriented independently of one another with respect to their orientation and independently of a superstructure of the crawler system for the definition of a movement of the crawler system, wherein the mobile crawler system has an open-loop/closed-loop control device, which is coupled to the chassis systems and the movement systems and is adapted to activate each of the chassis systems and movement systems individually and to set at least two of the following individual movement characteristics individually and to control

them in dependence on one another: path of movement, momentary orientation, speed of the respective chassis/movement system, wherein at least one of the chassis systems and the movement systems respectively comprise at least one crawler chassis, which is pivotable about a vertical axis and has a plurality of drive units, wherein at least one of the momentary direction of advancement of the respective chassis/movement system, and the path of movement, and the speed is specifiable exclusively by specification of an angular speed of individual drive units of the respective chassis/movement system, and wherein the open-loop/closed-loop control device is adapted to prioritize counter-controlling with respect to an individual deviation of at least one setpoint parameter for each chassis/movement system over counter-controlling of a deviation of at least one absolute setpoint parameter of the crawler system.

15. A mobile conveyor bridge system adapted for transporting material to be conveyed, having a bridge with a conveyor belt along a main axis of extent, wherein for movement on an underlying surface, the bridge is arranged on a plurality of chassis systems that are respectively pivotable about a vertical axis, furthermore having a spreading system, wherein the material to be conveyed can be transported on the conveyor belt from the bridge onto a discharge device by the spreading system, wherein for movement on the underlying surface, the spreading system having at least one movement system that can be pivoted about a vertical axis is decoupled from the bridge, wherein the spreading system comprises at least two carrier systems, which respectively have at least one movement system in order to move the spreading system on the underlying surface, wherein either each carrier system is arranged on the spreading system in such a way that at least two movement systems laterally enclose the main axis of extent of the bridge, or wherein each carrier system is arranged on the spreading system in such a way that the at least one movement system of the respective carrier system is arranged on one side in relation to the main axis of extent of the bridge, wherein the mobile conveyor bridge system has an open-loop/closed-loop control device, which is coupled to the chassis systems and the movement systems and is adapted to activate each of the at least three chassis systems and movement systems individually and to set at least two of the following individual movement characteristics individually and to control them in dependence on one another: path of movement, momentary orientation, speed of the respective chassis/movement system, wherein at least one of the chassis systems and the movement systems respectively comprise at least one crawler chassis, which is pivotable about a vertical axis and has a plurality of drive units, and wherein at least one of the momentary direction of advancement of the respective chassis/movement system,

the path of movement and the speed is specifiable exclusively by specification of an angular speed of individual drive units of the respective chassis/movement system, and wherein the open-loop/closed-loop control device is adapted to prioritize counter-controlling with respect to an individual deviation of at least one setpoint parameter for each chassis/movement system over counter-controlling of a deviation of at least one absolute setpoint parameter of the crawler system.

16. The device according to any one of claims 14 and 15, wherein at least one of
- the path of movement of the respective chassis/movement system is specifiable exclusively by individual activation of drive units of the chassis/movement system by setting individually differentiated propulsion at at least two drive units of the respective chassis/movement system that are offset transversely to one another in relation to the traveling direction; and
 - the respective chassis/movement system is mounted and can be oriented freely rotatably about an at least approximately vertically oriented pivot axis in a torque-free manner without a steering torque by controlling the individual advancement of individual drive units.

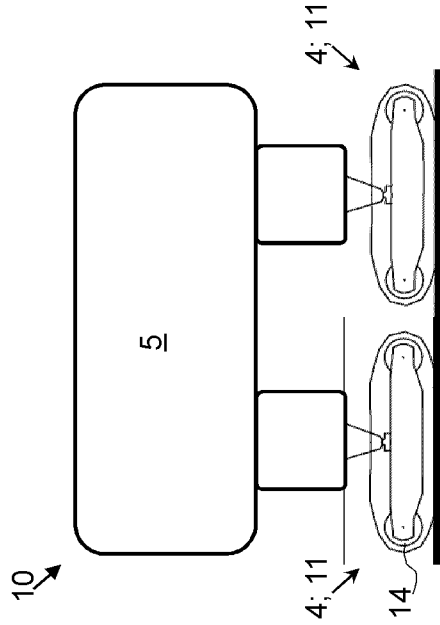


Fig. 1B

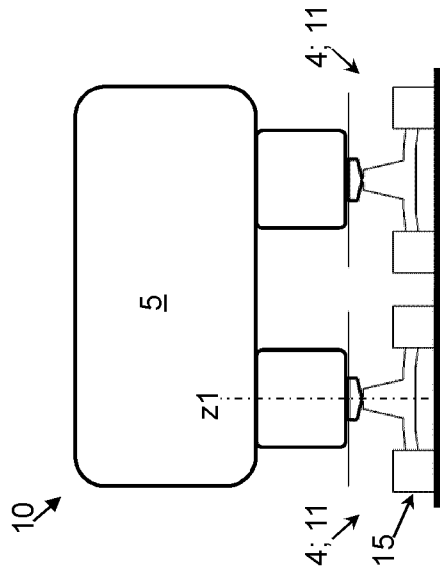


Fig. 1A

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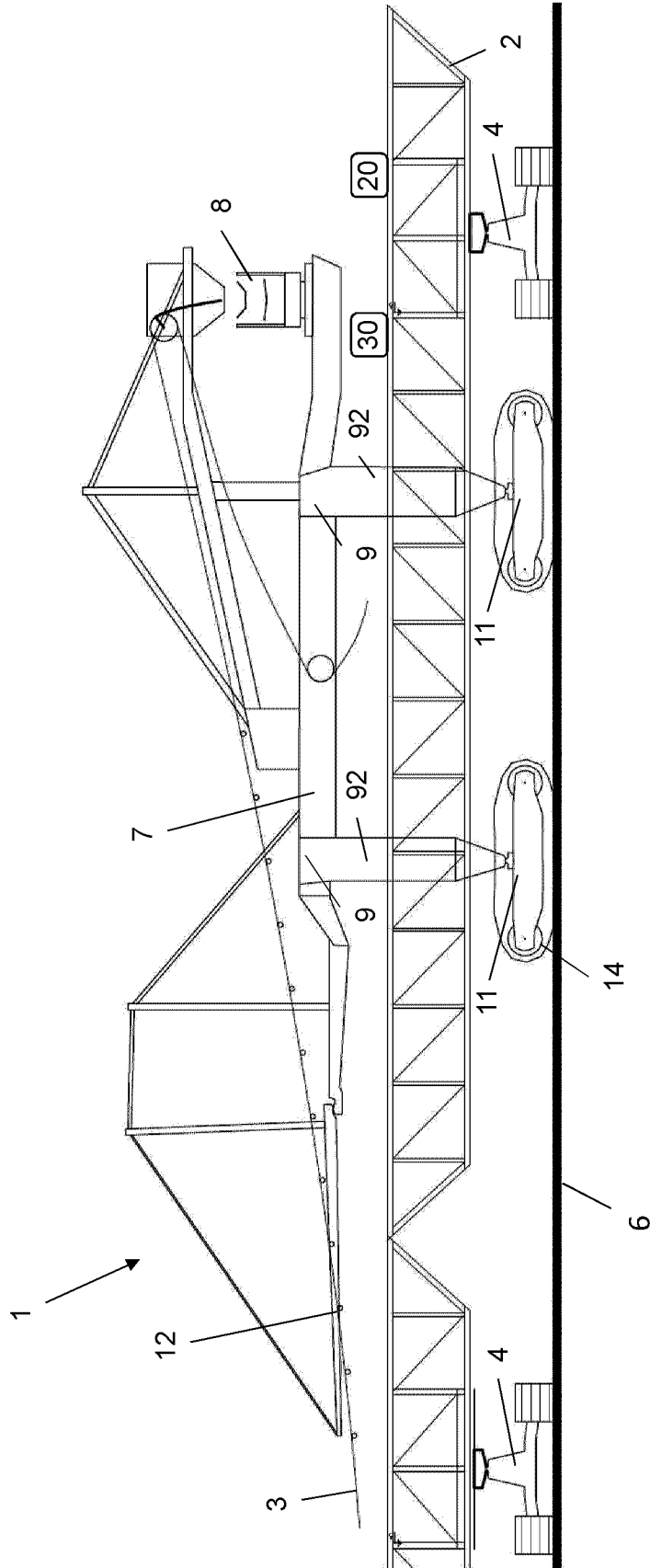


Fig. 2

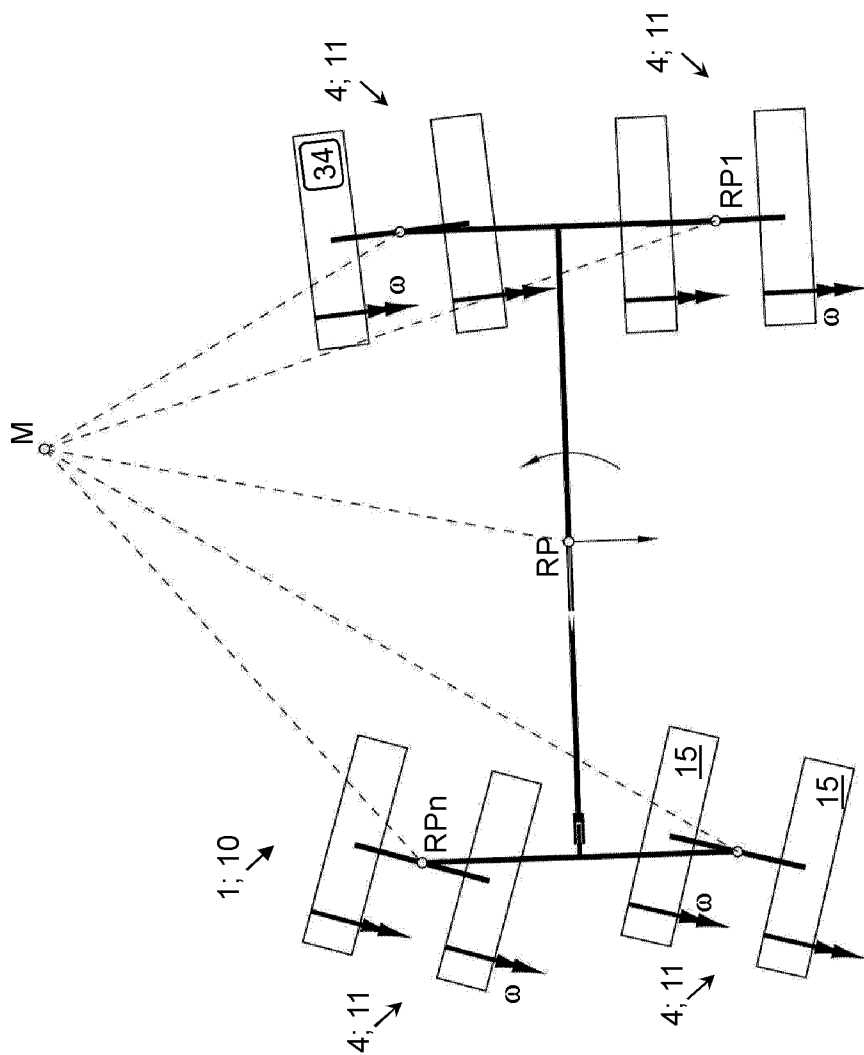


Fig. 3

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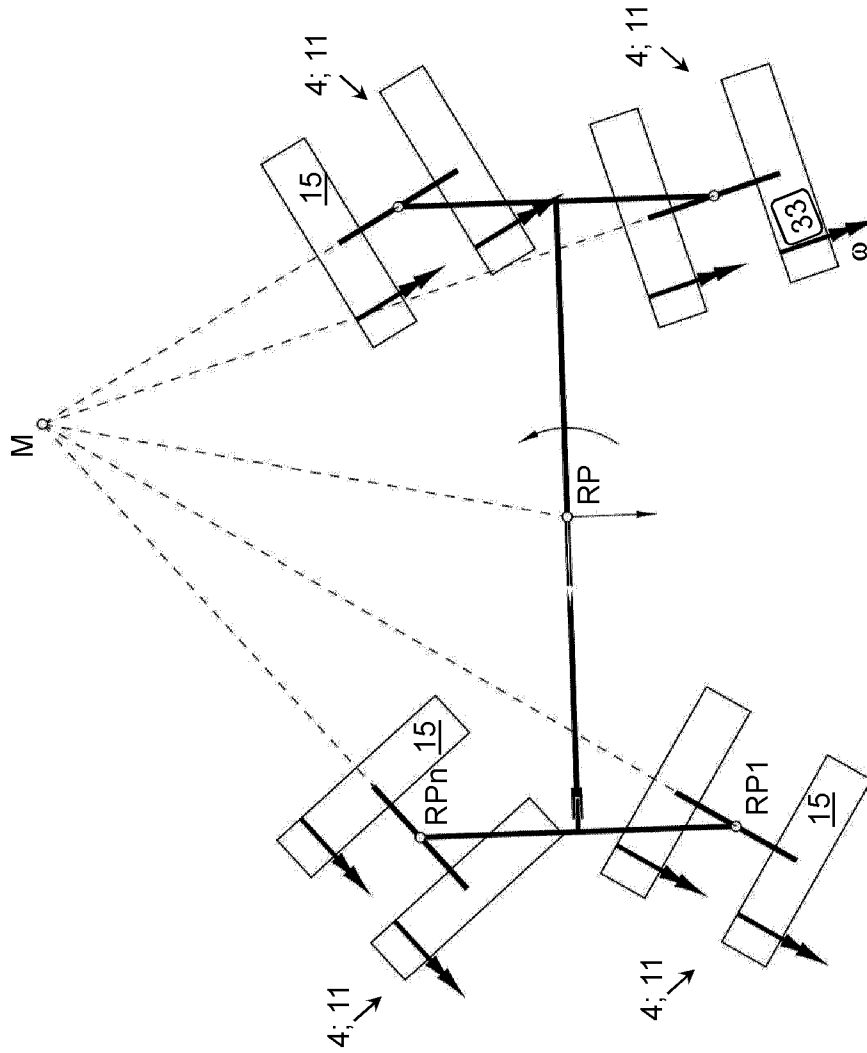


Fig. 4

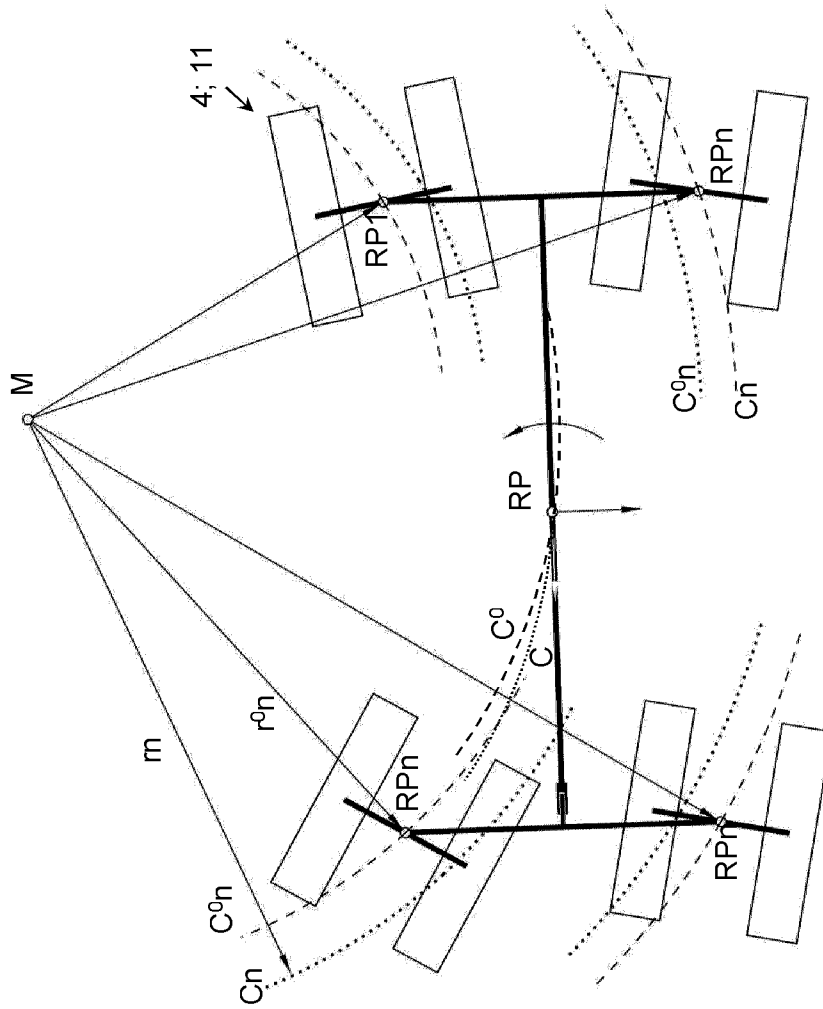


Fig. 5

