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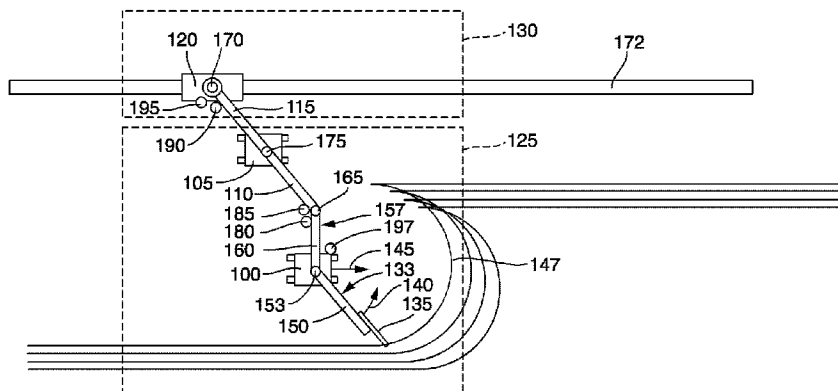
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(72) Inventeurs/Inventors:
NARO, DANIELE, DE;
WALTHER, JULIAN, DE;
GENIUS, WOLFGANG, DE;
SCHMITT, MARTIN, DE;
SEEHOFER, FRANK, DE

(73) Propriétaire/Owner:
FLSMIDTH A/S, DK

(74) Agent: KIRBY EADES GALE BAKER

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USED IN PARTICULAR IN SURFACE MINING



(57) **Abrégé/Abstract:**

The present invention relates to a method and an apparatus for operating a conveyor system, having at least two excavation and/or conveyor devices, for the removal of loose material excavated at an excavation site, wherein transfer points for the transfer of conveyed material are respectively arranged between the at least two excavation and/or conveyor devices, wherein in particular provision is made for spatial positions and/or orientations of at least two excavation and/or conveyor devices involved at a respective transfer point to be determined by sensors, and for the at least two excavation and/or conveyor devices involved at the respective transfer point to be actuated on the basis of the spatial positions and/or orientations determined, in such a way that the positions and/or orientations of the at least two excavation and/or conveyor devices in the region of the respective transfer point are adjusted.



Abstract

The present invention relates to a method and an apparatus for operating a conveyor system, having at least two excavation and/or conveyor devices, for the removal of loose material excavated at an excavation site, wherein transfer points for the transfer of conveyed material are respectively arranged between the at least two excavation and/or conveyor devices, wherein in particular provision is made for spatial positions and/or orientations of at least two excavation and/or conveyor devices involved at a respective transfer point to be determined by sensors, and for the at least two excavation and/or conveyor devices involved at the respective transfer point to be actuated on the basis of the spatial positions and/or orientations determined, in such a way that the positions and/or orientations of the at least two excavation and/or conveyor devices in the region of the respective transfer point are adjusted.

Description**METHOD AND APPARATUS FOR THE AUTOMATABLE OPERATION OF A
CONVEYOR BELT SYSTEM USED IN PARTICULAR IN SURFACE MINING**

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The invention relates to a method for the automated transfer of loose material at mobile and/or static conveyor belt devices or conveyor belt machines, used primarily in surface mining. The present invention also relates to a computer program, a machine-readable data medium for storing the computer program, and an apparatus by means of which the method according to the invention may be carried out.

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Prior Art

The material flow in the scope of a continuously operating conveyor belt system used in surface mining is transferred in a manner known per se at transitions between mobile and/or static material-carrying conveyor devices. In this case, free transfer of the material flow takes place at so-called transfer points by means of suitable conveyor transfer chutes or alternatively as free transfers without material guiding. By means of the conveyor devices, the material excavated by an excavating or mining excavator, for example a bucket wheel excavator, at an excavation front of an excavation site, or bulk material, is transferred usually to mobile belt bridges or belt wagons or the like, and ultimately to a rail-borne or chassis-based transport system with a running rail or hopper car (rail-borne or chassis-based) arranged on a stope belt, or to transport vehicles, for example autonomous or nonautonomous dumper trucks, for further transport.

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For the automation of maximally secure transfer of the material flow at the respective transfer points, it is necessary to orientate the conveyor devices precisely with respect to one another as a function of the available kinematic degrees of freedom of the conveyor devices respectively involved. The necessary alignment tasks resulting therefrom are usually carried out in the prior art by auxiliary personnel in order to ensure that the material flow is transferred continuously and without losses to the respectively following conveyor device of an overall conveyor system even during a translational movement process of a plurality of conveyor devices of a device assembly respectively present.

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From WO 2015/055236 A1, a method is known for positioning two devices with respect to one another that carry out transfer of bulk material, at least one of which being movable and a material discharge or material receiving portion arranged thereon to be aligned with the material discharge or the material receiving portion of the respective other device.

- 5 Attached to the one device, there are multidimensionally imaging radar sensors which periodically record the environment of the material discharge or material receiving portion of the other device and receive the reflection of emitted radar beams on a reflection ring, which is attached to the respective other device and surrounds the material discharge or the material receiving portion arranged on this device, and transmit corresponding raw
- 10 data to a calculation unit. In the calculation unit, the spatial position, stored in the calculation unit, of each radar sensor on the device in an assigned relative coordinate system with the spatial coordinates X, Y, Z is set in relation to the spatial position, determined in the calculation unit, of the reflection points caused by the incidence of the radar beams emitted by each radar sensor on the reflection ring in an assigned relative
- 15 coordinate system with the spatial coordinates X, Y, Z. The position of the devices with respect to one another is then changed until the position relationship of the radar sensors with respect to the reflection points assigned thereto corresponds to a specified setpoint value.

20 Disclosure of the Invention

The invention is based on the idea, in order to allow a maximally continuous material flow in a conveyor belt system of the type in question here, arranged at an excavation site, in particular at aforementioned transfer points between at least two conveyor devices, to carry out automatic adjustment of the conveyor devices arranged at the so-called transfer points by open-loop control or closed-loop control of relevant degrees of freedom relating to the local position of the conveyor devices involved at a transfer point and/or preferably the horizontal (angular) orientation of the conveyor devices thus involved.

- According to the method according to the invention and the apparatus, location and/or angle data, determined by sensors and/or derived on the basis of a model, of the
- 25 conveyor devices involved are processed, as much as possible in real time, for the required precise orientation of the conveyor devices of the type in question here at the respective transfer points.

According to one aspect of the proposed method, the method may be subdivided procedurally into the following three technical segments:

- 5 1. According to a first procedural segment, real-time recording by sensors of local positions and/or angular orientations of the excavation/conveyor devices involved at least at one transfer point is carried out. These devices preferably relate to a device assembly, locally present at an excavation front or mining edge, of an excavation or conveyor system of the type in question here. The determination of the respective transfer points is in this case carried out on the basis of a model
10 with the aid of device-intrinsic position and/or operating data, for example by means of suitable angle encoders or by means of optical image recognition arranged outside the conveyor devices.

15 In addition, the recording by sensors may in this case be carried out by means of radar with the aid of at least one reference object, for example a reflector ring, by means of lidar (= light detection and ranging), by means of transponder technology known per se according to the time-of-flight principle or the like, or by means of camera technology known per se.

20 As an alternative or in addition, the recording may be carried out by means of satellite-based GNSS positioning of material discharge and material receiving regions, present at the respective transfer points, of the conveyor devices involved. For reasons of accuracy, a D-GPS (Differential GPS) positioning system is preferably used in this case.

- 25 2. According to a second procedural segment of the method according to the invention, suitable process variables for the operation of the conveyor system present are determined, by means of which the position and/or horizontal orientation of the conveyor devices involved can be adjusted as accurately as possible in relation to the respective transfer points. In this case, superordinate
30 excavation process planning of respectively following working steps, or corresponding path planning of the excavator, or of the at least locally present conveyor devices, optionally spanning a device assembly, may be calculated in advance.

5 A model, preferably present in the process planning, for the entire excavation process may in this case also comprise environment detection at the excavation front of a mining machine present (for example a bucket wheel excavator) as well as of conveyor devices involved in the vicinity of the mining machine, specifically including any existing embankment geometries and/or possible obstacles in the region of the excavation front.

10 3. According to a third procedural segment of the method according to the invention, the control of the entire device assembly of the conveyor system present is carried out with the aid of suitable driving instructions and/or tilting/lifting movements of the excavation/conveyor devices involved, specifically by means of a superordinate control logic or a corresponding control algorithm.

15 The control logic or control algorithm is preferably constructed in a modular fashion so that expansion and simplification of the excavation and/or conveyor devices involved in the device assembly is possible by corresponding parameterization. Thus, it is possible to reduce the number of conveyor devices and/or the respective degrees of freedom per conveyor device. In addition, individual devices may situation-dependently be "docked" in a simplified way to further devices.

25 According to a further aspect of the proposed method, the aforementioned logic or the algorithm may be control-based, the control behavior of the entire device assembly being mapped in a control structure and therefore not being rigidly specified for all operating situations of the conveyor system. The corresponding control algorithm may in addition be configured to be generic or else self-learning, for example by means of an artificial neural network (ANN). The automatic adjustment of at least two excavation and/or conveyor devices involved at the respective transfer point may therefore be carried out by means of open-loop control and/or closed-loop control of relevant degrees of freedom in the movement of the at least two excavation and/or conveyor devices in the region of the respective transfer point. The position of the excavation and/or conveyor devices involved at the respective transfer point and/or the horizontal and/or vertical orientation of the excavation and/or conveyor devices involved at the respective transfer point may in this case be used as relevant degrees of freedom.

According to a further aspect, it may be provided that the proposed method is also used for controlling a conveyor system, a suitable sensor system or a model-based simulation being used to establish whether the speed of the conveying process should be modified or adjusted in the event of a varying material workload. Such adjustment may in particular
5 be carried out with a view to reliable material transfer at the respective transfer points and/or with a view to any subsequent classification and/or size reduction processes. This is because a relatively coarse mined material slows the size reduction process, while a relatively fine workload material may overwhelm any subsequent crushing system with material because of the insufficient speeds of the units of the crushing system.

10 It should in this case be pointed out that even existing conveyor systems, automated at least partially by means of a sensor system, may still be substantially improved retrospectively with the aid of the method according to the invention, in particular when carrying out an aforementioned process simulation.

15 According to a further aspect, it may be provided that suitable location and/or angle data of the excavation and/or conveyor devices involved at the respective transfer point, with the aid of which precise orientation of the excavation and/or conveyor devices in the region of the respective transfer point is carried out, are in this case calculated by means
20 of a model calculation with the aid of the spatial positions and/or orientations, determined by sensors, of at least two excavation and/or conveyor devices involved at the respective transfer point.

25 According to a further aspect, it may be provided that the adjustment of spatial positions and/or orientations of the at least two excavation and/or conveyor devices in the region of the respective transfer point is carried out control-based, the closed-loop control or open-loop control behavior of the at least two excavation and/or conveyor devices involved at a respective transfer point being mapped in a control structure. In this case, it may also be provided that the control-based adjustment of the spatial positions and/or orientations of
30 the at least two excavation and/or conveyor devices in the region of the respective transfer point is carried out by means of a self-learning algorithm.

According to a further aspect, it may be provided that the actuation of the at least two excavation and/or conveyor devices involved at a respective transfer point is carried out as a function of a varying speed of the conveying process.

According to a further aspect, to be carried out with a conveyor belt system having an excavator, at least one belt wagon and a hopper car, it may be provided that the rate of advance and the rotation angle of the belt wagon in relation to a discharge boom of the excavator and the position of the hopper car are used as control variables in the actuation
5 of at least two excavation and/or conveyor devices involved at the respective transfer point. In this case, it may be provided that the rate of advance of the excavator in the direction of the excavation site is furthermore specified in such a way that the conveyor belt system is optimally utilized overall.

10 Lastly, according to yet another aspect, it may be provided that a first material flow in a first conveying system of the conveyor belt system and a second material flow in a second conveying system of the conveyor belt system are recorded by sensors, and in the event of an existing difference of the first and second material flows, suitable adjustment, by which the existing deviation is compensated for, of the rate of advance of
15 the excavator is carried out.

The apparatus likewise proposed according to the invention is configured to control a conveyor system of the type in question here, in particular the spatial movement and/or the spatial orientation of the conveyor devices respectively involved, in a substantially
20 automated fashion during the excavation or mining process by means of the proposed method.

According to one aspect, the proposed apparatus may have a sensor system for determining spatial positions and/or orientations of excavation and/or conveyor devices
25 involved at a respective transfer point, a calculation module for carrying out planning of the excavation process on the conveyor belt system with the aid of the spatial positions and/or orientations determined and on the basis of a data model of the excavation process, as well as an open-loop controller and/or closed-loop controller for the actuation and/or controlled actuation of the excavation and/or conveyor devices involved at the
30 respective transfer point with the aid of the planned excavation process.

The invention may, in particular, be employed in an excavation and/or conveyor system usable primarily above ground in (above) surface mining for ore or lignite coal excavation, but in principle also below ground in underground mining for ore, anthracite coal, sand or
35 rock extraction. Use in excavation and/or conveyor systems for extracting loose raw materials for cement production, or else in other industrial systems in which loose

materials or substances need to be conveyed over a relatively long distances by means of a conveyor belt technology of the type in question here, may correspondingly also be carried out.

- 5 The computer program according to the invention is configured to carry out each step of the method, in particular when it runs on a computer device or a control device. It allows implementation of the method according to the invention on an electronic control device, without structural modifications having to be carried out on the latter. For this purpose, the machine-readable data medium, on which the computer program according to the
- 10 invention is stored, is provided. By executing the computer program according to the invention on an apparatus, or a corresponding electronic control device, the apparatus according to the invention is obtained, which is configured to operate a conveyor belt system of the type in question here by means of the method according to the invention, or to control the corresponding conveyor operation.

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Further advantages and configurations of the invention may be found in the description and the appended drawings. In the drawings, elements or features that are identical or functionally equivalent are provided with the same references.

- 20 It is to be understood that the features mentioned above and those yet to be explained below may be used not only in the combination respectively specified but also in other combinations or separately, without departing from the scope of the present invention.

Brief Description of the Drawings

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Figure 1 shows a schematic plan view of a typical spatial arrangement of a mining or bucket wheel excavator together with corresponding conveyor devices at an excavation or mining edge of an ore deposit, including a sensor system according to the invention.

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Figure 2 shows an exemplary embodiment of the method according to the invention, or the apparatus, with the aid of a combined flowchart/block diagram.

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Figure 3 shows an exemplary embodiment of a sensor-based simulation calculation according to the invention for the automated operation of a conveyor system of the type in question here.

Description of Exemplary Embodiments

The method according to the invention for operating a conveyor system of the type in question here and a corresponding control apparatus will be described below with
5 reference to the exemplary embodiment of an above-ground conveyor system used in the extraction of ore by means of a bucket wheel excavator. The method and the apparatus may, however, also be used correspondingly in above-ground or underground excavation/conveyor systems used in another way, for example for ore, coal, sand or rock extraction.

10

A conveyor system of the type in question here usually consists of a plurality of material conveyor devices cooperating with an excavator. The spatial arrangement or orientation of the conveyor devices with respect to one another and relative to the excavator during an excavation process or mining process may be computer-modeled. The process part
15 most influenceable for the modeling is in this case the accurate positioning and spatial orientation of conveyor bridges, or belt wagons, arranged between the excavator and a hopper car.

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Figure 1 shows an exemplary device arrangement, or device assembly, consisting of an excavator 100, in the present case a bucket wheel excavator for surface mining, arranged at an excavation front, a belt wagon 105 with a receiving boom 110 and a discharge boom 115, as well as a hopper car 120 arranged in the present exemplary embodiment on a running rail.

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It should in this case be pointed out that the device assembly consisting of the bucket wheel excavator 100 and the belt wagon 105 in the present exemplary embodiment represents a first conveying system according to the broken line 125 and that the hopper car 120 movable on the running rail represents a correspondingly second conveying system according to the broken line 130. The first conveying system 125 is therefore
30 used essentially for near-excavation transport of the bulk material away, and the second conveying system 130 with the hopper car 120 is essentially used for further conveying of the already excavated bulk material to a loading site relatively far away, for example for loading the bulk material onto a transport vehicle, for example a truck, or a further rail vehicle, for example a freight train.

It should furthermore be pointed out that, according to an alternative device arrangement or according to an alternative use scenario, the bucket wheel excavator 100 may also deliver bulk material directly to the hopper car 120, no belt wagon 105 being arranged between them in this scenario.

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In a manner known per se, the bucket wheel excavator 100 has a bucket wheel 135 mounted rotatably in the horizontal ground plane (= plane of the drawing), and usually also perpendicularly thereto, on a first conveyor boom 133. By a horizontal transverse movement of the first conveyor boom 133, and therefore also of the bucket wheel 135, corresponding to a first arrow direction 140 and a forward movement of the bucket wheel 135, or correspondingly of the excavator 100, in a second arrow direction 145 at a so-called "mining edge" 147, loose material is excavated or mined.

The bulk material excavated by the bucket wheel excavator 100 is fed by means of a first conveyor belt 150 arranged on the first conveyor boom 133 at a fixed transfer or connecting site 153 provided on the bucket wheel excavator 100 to a material-removing second conveyor belt 160 arranged on a second conveyor boom 157.

At a first transfer point (TP1) 165, transfer of the bulk material delivered by the bucket wheel excavator 100 to the belt wagon 105 takes place. The non-fixed transfer at the transfer point (TP1) 165 of the bucket wheel excavator 100 must progressively be brought as much as possible into spatial correspondence with the receiving boom 110 of the belt wagon 105 during the excavating or mining operation of the bucket wheel excavator 100, i.e. in particular during a forward movement of the excavator in the second arrow direction 145 with a simultaneous rotational movement of the bucket wheel, so that during the transfer no bulk material falls down from the second conveyor belt 160 and/or the receiving boom 110 and is therefore lost for the excavation process.

In the present exemplary embodiment, the transfer point of the discharge boom 115 of the belt wagon 105 to the hopper car 120 represents a second, likewise non-fixed transfer point (TP2) 170, since the hopper car 120 also needs to be readjusted correspondingly in the direction of advance 145 of the bucket wheel excavator 100.

It should in this case be highlighted that in the present exemplary embodiment the receiving boom 110 and the discharge boom 115 of the belt wagon 105 are rotatably

mounted on a trailer 175 and connected to one another in a fixed fashion, and therefore cannot be horizontally moved independently of one another.

5 It should, however, be pointed out that the present invention in principle also comprises use scenarios in which the receiving boom 110 and the discharge boom 115 of the belt wagon 105 are mounted rotatably (turnably) relative to one another on the trailer 175. It should in this case furthermore be highlighted that the present invention comprises all possible ways of arranging conveyor devices of the type in question here, at least one access by actuators and/or sensors to the essential movable degrees of freedom of the
10 devices respectively in question being required.

The respectively free transfer of the bulk material at the two transfer points (TP1) 165 and (TP2) 170 in the present exemplary embodiment therefore requires constant adjustment, or realignment, of the respective two transfer points 165, 170 during the forward
15 movement of the bucket wheel excavator 100 in the second arrow direction 145, specifically between the bucket wheel excavator 100 and the belt wagon 105 on the one hand and between the belt wagon and the hopper car 120 on the other hand. In the present exemplary embodiment, the hopper car 120 represents a rail-borne transport vehicle of a corresponding rail network 172.

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It should in this case be pointed out that, instead of the rail network 172, specifically for further transport of excavated bulk material from the excavation front or from the aforementioned second conveying system 130, a stope belt configured as a belt conveyor or a transport vehicle, for example an autonomously or nonautonomously operated
25 dumper truck, may also be provided.

Furthermore, for its optimal operation, the entire conveyor system also requires optimal utilization of the first conveying system 125 and of the second conveying system 130. In addition to the requirement that as much as possible there must be no mining losses at
30 the respective transfer points 165, 170, the load distribution in the entire conveyor system should therefore also take place as homogeneously as possible. At the same time, respectively permitted maximum mining quantities or corresponding mining weights for the respective conveyor devices should not be exceeded.

35 It should be pointed out in this regard that such a load distribution of the material flow is preferably only carried out behind an aforementioned excavator 100 (or a mobile crusher

or the like), specifically in that region of a conveyor system of the type in question here in which an existing material flow of excavated or mined bulk material is conveyed via aforementioned conveyor devices and corresponding transfer points.

- 5 The aforementioned requirements for the operation of a conveyor system shown in Figure 1 may be satisfied with the aid of the method according to the invention and the apparatus, which allows automation of the adjustment of the respective transfer points by means of a suitable sensor system and an aforementioned model calculation. The accuracy of the correspondingly required dynamic adjustment of the position and/or
10 orientation of the conveyor devices respectively present may furthermore be additionally improved by a learning method, for example by means of an artificial neural network (ANN).

In the present exemplary embodiment, the aforementioned sensor system comprises
15 respectively cooperating transponder pairs 180, 185 and 190, 195 arranged at the respective transfer points (TP1, TP2) 165, 170. The first transponder 180 is in this case arranged on the second conveyor boom 157 of the bucket wheel excavator 100 and the second transponder 185 is arranged on the receiving boom 110 of the belt wagon 105. The third transponder 190 is arranged on the discharge boom 115 of the belt wagon 105
20 and the fourth transponder 195 is arranged on the hopper car 120. The transponder pairs 180 - 195 may be formed either respectively by two active transponders, i.e. two transponders equipped with their own energy supply, or by respective combination of one active and one passive transponder. By means of the transponders, it is possible to establish automatically whether the two end regions of the conveyor devices 100, 105,
25 120 involved at a transfer point 165 or 170 lie close enough to one another, or above one another, so that no bulk material is lost from the conveyor system during the transfer.

It should furthermore be pointed out that preferably both absolutely measuring position sensors and relatively measuring sensors are a prerequisite for the aforementioned
30 modeling of an existing operating situation of a device assembly of the type in question here. In this case, these two sensor types may be based on very diverse or different physical measurement principles.

Figure 2 shows an exemplary embodiment of the method according to the invention, or
35 the apparatus, with the aid of a combined block diagram/flowchart. The method shown is based in the present exemplary embodiment on a known sensor system, in the present

case based on transponder technology, for recording relevant location data of the conveyor devices 100, 105, 120 involved at the respective transfer points (TP1, TP2) 165, 170.

5 As an alternative or in addition, the required sensor system may be produced on the basis of radar or on the basis of light, for example by means of a "lidar" system, which is then likewise arranged in the regions of the transfer points 165, 170 (see Figure 1) of the conveyor devices respectively involved. As an alternative or in addition, the positions and/or orientations of the excavation/conveyor devices 100, 105, 120 involved at the
10 transfer points 165, 170 may also be determined by means of satellite-based GNSS data. In this case, depending on the location of use, the best satellite positioning systems available there may be employed. As an alternative or in addition, an optical sensor system, for example by means of IR sensors, laser sensors, or a sensor system based on camera technology known per se may also be employed.

15 At the excavator 100, environment detection 197 likewise preferably operating by sensors may additionally be provided for spatial monitoring of the mining edge 147 and in particular of possible obstacles, for example vegetation standing in the way or a group of trees (embankment), in order also to be able to carry out precise and reliable planning of
20 the entire excavation and mining process in advance for the operation according to the invention of an excavation/conveyor system of the type in question here.

The method shown in Figure 2 is additionally based in the present exemplary embodiment on a computer-assisted model simulation of a (local) conveyor device
25 assembly shown in Figure 1. The model simulation comprises on the one hand a model-based calculation of possible movement processes (kinematics) of the conveyor device assembly respectively present, i.e. in particular of the positions and/or orientations of these devices or machines that occur during possible movement processes of the excavation/conveyor devices 100, 105, 120 involved there.

30 Furthermore, the model calculation in the exemplary embodiment comprises a calculation model 200 of the excavation process per se, i.e. the material quantity and/or size distribution of the corresponding debris or bulk material occurring for an assumed lateral excavation movement of the bucket wheel 135 of an excavator 100 shown in Figure 1.
35 With the aid of the model calculation, the local excavation/conveyor device assembly composed of the two conveying systems 125, 130 is furthermore operated in such a way

that the two conveying systems 125, 130 are utilized as much as possible optimally. In this case, a maximally homogeneous load distribution of mining or bulk material of the excavation/conveyor devices 100, 105, 120 involved, a maximum mining quantity and the least possible or even no mining or material losses at the transfer points 165, 170 may be sought.

Planning of the excavation process, in particular of the correspondingly required adjustment of the entire local conveyor chain, or the locally involved excavation/conveyor devices 100, 105, 120, is carried out by means of a calculation module 210 with the aid of the location data 205, delivered by the sensor system 180 - 195, relating to the described transfer points. In this case, possible degrees of freedom in the movement of the excavation/conveyor devices 100, 105, 120 are taken into account. The planning of the excavation process is based, in particular, on the knowledge that the spatial orientation of the individual devices of a device assembly of the type in question here may always be (automatically) orientated on a guiding device. As already mentioned, the model of the excavation process may additionally be based on sensor data of an aforementioned environment detection 197.

During the predictive planning of the movement of the local excavation/conveyor device assembly, possible passages of time or time-dependent movement profiles in the operation of the excavator 100 or of its bucket wheel 135 and in the movement of the belt wagon 105 and of the hopper car 120 are calculated.

With the aid of the aforementioned further constraints, for example the maximally homogeneous load distribution and avoidance of exceeding a maximum permitted mining quantity, the entire device assembly is actuated 215 by means of a controller, for example a programmable logic controller (PLC) known per se. The actuation may be carried out in a manner known per se by means of corresponding driving instructions to the bucket wheel excavator 100, corresponding tilting movements of the bucket wheel 135 and corresponding driving instructions to the mobile conveyor bridge 110. 115 of the belt wagon 105. The driving instructions may for example relate to an adjustment, concerning a forward movement value, of the positions and/or alignment of the excavation/conveyor devices involved. These adjustments ensure that as far as possible no mined material falls down from a conveyor belt at the transfer points (TP1, TP2) 165, 170 of the type in question here and is therefore lost for the further conveying process.

Instead of predictive planning as described, the described method may also be configured as an ANN-based system capable of learning or as an automated control system or as a self-learning regulator. In such a control system, either a desired mining quantity of the entire excavation process of the excavation/conveyor device assembly
 5 present or a forward movement value, correlating with the desired mining quantity, of the excavator 100 may be specified as a setpoint variable. The current value of the forward movement of the excavator 100 as an actual variable may therefore be adjusted by means of the closed-loop control in such a way that the movement of the currently involved excavation/conveyor devices 100, 105, 120 that is required for loss-free transfer
 10 of the mined material at the transfer points (TP1, TP2) 165, 170 is carried out.

In Figure 3, the calculation mentioned in Figure 2 is represented in more detail with the aid of an exemplary embodiment. In this case, it is again assumed that the conveyor system shown in Figure 1 comprises a bucket wheel excavator 100, a belt wagon 105
 15 and a hopper car 120. It should, however, be pointed out that further transfer points would correspondingly need to be taken into account in exemplary embodiments having two or more belt wagons, for example three transfer points with an additional transfer point (not shown here) in the case of two belt wagons.

20 Because of the fixed arrangement of the receiving boom 110 shown in Figure 1 in relation to the discharge boom 115 of the belt wagon 105, the present optimization or alignment problem comprises the two location variables of a suitable transfer point (TP1) 165 and of a suitable transfer point (TP2) 117. The optimization is used to ensure that the end regions of the excavation/conveyor devices 100, 105, 120 are arranged as much as
 25 possible above one another at the transfer points (TP1, TP2) 165, 170 at any time in the excavation process.

In this alignment or optimization problem, in the present exemplary embodiment the rate of advance and the rotation angle or the orientation of the belt wagon 105 in relation to
 30 the discharge boom 157 of the bucket wheel excavator 100 as well as the position of the hopper car 120 along the rail 172 are used as influencing quantities for the adjustment. The rate of advance of the bucket wheel excavator 100 in the second arrow direction 145 shown in Figure 1, in the direction of the mining edge 147, is in this case specified in such a way that the two conveying systems 125, 130 are utilized optimally with the greatest
 35 possible material (quantity) throughput.

15

The following quantities that may be measured or determined by means of the sensor system 180, 185, 190, 195 are used as possible variable operating quantities for the optimization:

- 5 - the rotation angle and the height position of the discharge boom 157 of the bucket wheel excavator 100,
- the position of the belt wagon 105,
- the rotation angle and the height position of the conveyor bridge 110, 115 of the belt wagon 105 as well as all individually movable booms arranged there, and
- 10 - the position of the hopper car 120 along the rail 172.

From the position data recorded by means of the sensor system 180 - 195, the aforementioned angle data may also be calculated in a manner known per se. Thus, from the position data recorded by means of the two sensors 185, 190, not only the horizontal
 15 position of the two end regions of the receiving boom 110 and of the discharge boom 115 of the belt wagon 105 but also the horizontal angle of the conveyor bridge formed by the receiving boom 110 and the discharge boom 115, for example in relation to the direction of advance 145 of the bucket wheel excavator 100, may be determined trigonometrically in a manner known per se.

20 In the routine shown in Figure 3, both a current first material flow 300 in the first conveying system 125 and a current second material flow 305 in the second conveying system 130 are initially recorded, or determined, by means of a sensor system (not shown here) known per se. These two values 300, 305 are fed to a first calculation
 25 module 310, in which a suitable adjustment of the rate of advance of the bucket wheel excavator 100, by which the possible deviation may be removed or compensated for, is calculated from a possible deviation of the two values 300, 305.

30 By means of the forward movement data obtained during the calculation 310, the bucket wheel excavator 100 is actuated 315 with a correspondingly specified rate of advance.

On the basis of the rate of advance thereby obtained of the bucket wheel excavator 100, and in particular on the basis of the aforementioned position data 325 currently recorded by the sensor system 180 - 195, a model calculation or simulation of the entire
 35 excavation/conveyor chain 100, 105, 120, including the booms 157, 110, 115, is carried out by means of a second calculation module 320 in order to determine suitable control

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- interventions or measures in the operation of the discharge boom 157 of the bucket wheel excavator 100, of the belt wagon 105 and of the hopper car 120. The aim to be achieved by means of these measures is that the excavation/conveyor devices involved are oriented as accurately as possible at the aforementioned transfer points 165, 170 for the
- 5 reasons above. These measures or adjustments may therefore be carried out almost in real time, particularly in the case of a possibly existing change in the rate of advance of the bucket wheel excavator 100. These measures are additionally converted in the second calculation module into changes of the aforementioned variable quantities.
- 10 The changes, obtained from the model calculation 320, of the aforementioned variable quantities are converted by means of a third calculation module 330 into specific control instructions or modified control instructions for the operation of the excavation/conveyor devices 100, 105, 120 involved. By means of these control instructions, the excavation/conveyor devices 100, 105, 120 are finally actuated 335.
- 15 The start of the routine is then returned to and current material flows 300, 305 in the two conveying systems 125, 130 are again recorded, or determined. From this, a suitable adjustment of the rate of advance of the bucket wheel excavator 100 is again calculated and the routine is continued as described in order to allow automation of the described
- 20 optimization process.
- It should be emphasized that the three calculation modules 310, 320 and 330 may also be implemented in the form of a single calculation module, since the calculation architecture is not important in the present case.
- 25

Patent Claims

1. A method for operating a conveyor belt system having at least two devices selected from the group consisting of excavation devices and conveyor devices, for removal of loose material excavated at an excavation site, wherein transfer points for transfer of conveyed material are respectively formed between the at least two devices, at least one of spatial positions and orientations of any of the at least two devices involved at a respective transfer point are determined by sensors, and the any of the at least two devices involved at the respective transfer point are actuated on the basis of the at least one of spatial positions and orientations determined in such a way that the at least one of spatial positions and orientations of the any of the at least two devices in a region of the respective transfer point are adjusted, wherein determination by the sensors of the at least one of spatial positions and orientations of the any of the at least two devices involved at the respective transfer point is carried out on the basis of a model with the aid of at least one of device-intrinsic position and operating data of the any of the at least two devices involved, automatic adjustment of the any of the at least two devices involved at the respective transfer point is carried out by means of at least one of open-loop control and closed-loop control of relevant degrees of freedom in the movement of the any of the at least two devices in the region of the respective transfer point, adjustment of the at least one of spatial positions and orientations of the any of the at least two devices in the region of the respective transfer point is additionally carried out with the aid of a time-of-flight evaluation of at least one of material discharge and material receiving behavior, existing at the respective transfer point, of conveyed bulk material.
2. The method as claimed in claim 1, wherein at least one of position, horizontal orientation and vertical orientation of the any of the at least two devices involved at the respective transfer point are used as relevant degrees of freedom.
3. The method as claimed in any one of claims 1 to 2, wherein at least one of suitable location and angle data of the any of the at least two devices involved at

the respective transfer point, with the aid of which precise orientation of the any of the at least two devices in the region of the respective transfer point is carried out, are calculated with the aid of the at least one of spatial positions and orientations determined by sensors of the any of the at least two devices involved at the respective transfer point by means of a model calculation.

4. The method as claimed in any one of claims 1 to 3, wherein determination by the sensors of the at least one of spatial positions and orientations of the any of the at least two devices involved at the respective transfer point is carried out by means of at least one of radar with the aid of at least one reference object, lidar, transponder technology, satellite-based GPS positioning, and camera technology.
5. The method as claimed in any one of claims 1 to 4, wherein objects detected by means of an environment detection carried out in a surrounding region of the at least two devices involved are taken into account in the adjustment of the at least one of spatial positions and orientations of the any of the at least two devices in the region of the respective transfer point.
6. The method as claimed in any one of claims 1 to 5, wherein the adjustment of the at least one of spatial positions and orientations of the any of the at least two devices in the region of the respective transfer point is carried out control-based, the closed-loop control or open-loop control behavior of the any of the at least two devices involved at the respective transfer point being mapped in a control structure.
7. The method as claimed in claim 6, wherein the control-based adjustment of the at least one of spatial positions and orientations of the any of the at least two devices in the region of the respective transfer point is carried out by means of at least one of a generic algorithm and a self-learning algorithm.
8. The method as claimed in any one of claims 1 to 7, wherein actuation of the any of the at least two devices involved at the respective transfer point is carried out as a function of a varying speed of the conveying process.
9. The method as claimed in any one of claims 1 to 8, wherein the conveyor belt system having the at least two device which comprise an excavator, at least one

belt wagon and a hopper car, wherein a rate of advance and rotation angle of the belt wagon in relation to a discharge boom of the excavator and in relation to a position of the hopper car are used as control variables in actuation of the any of the at least two devices involved at the respective transfer point.

10. The method as claimed in claim 9, wherein a rate of advance of the excavator in a direction of the excavation site is specified based on utilization of the conveyor belt system in respect of the material flow of bulk material.
11. The method as claimed in claim 10, wherein a first material flow in a first conveying system of the conveyor belt system and a second material flow in a second conveying system of the conveyor belt system are recorded by the sensors, and in an event of an existing difference of the first and second material flows, suitable adjustment, by which existing deviation is compensated for, of the rate of advance of the excavator is carried out.
12. A computer readable medium having stored thereon statements and instructions that when executed by a computer device cause the computer device to execute the method according to any one of claims 1 to 12.
13. An apparatus which is configured to control a conveyor belt system for conveying material in the form of rock, the apparatus comprising:
a computer device configured to execute the method as claimed in any one of claims 1 to 13.
14. The apparatus as claimed in claim 14, further comprising a sensor system for determining at least one of spatial positions and orientations of at least one of excavation devices and conveyor devices involved at a respective transfer point, a calculation module for carrying out planning an excavation process on the at least one of excavation devices and conveyor devices with the aid of the at least one of spatial positions and orientations determined, as well as at least of an open-loop controller and a closed-loop controller for actuation of the at least one of excavation devices and conveyor devices involved at the respective transfer point with the aid of the excavation process.

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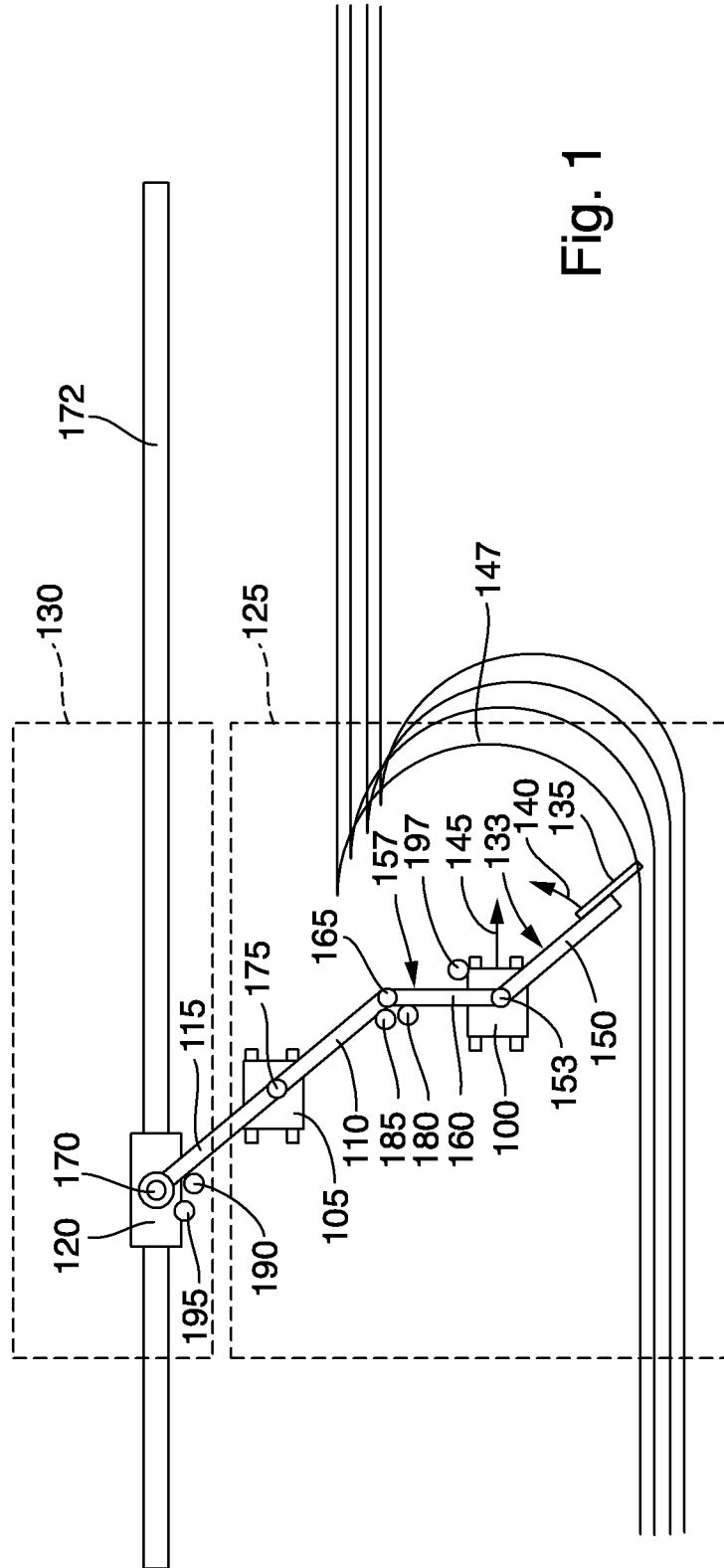


Fig. 1

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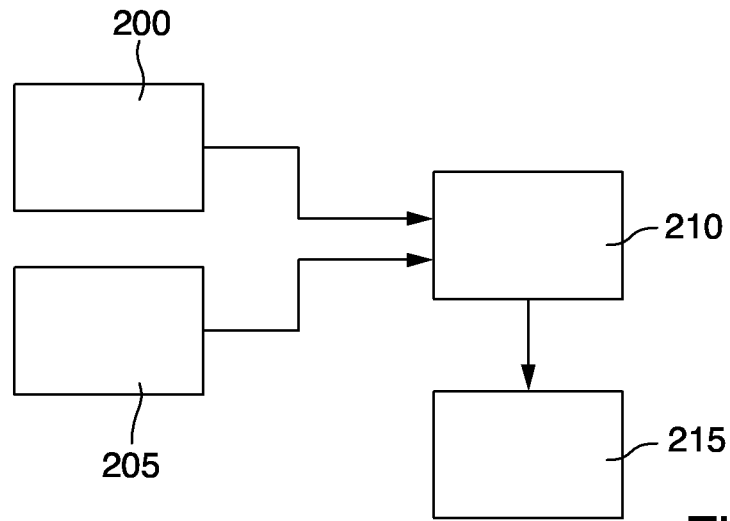


Fig. 2

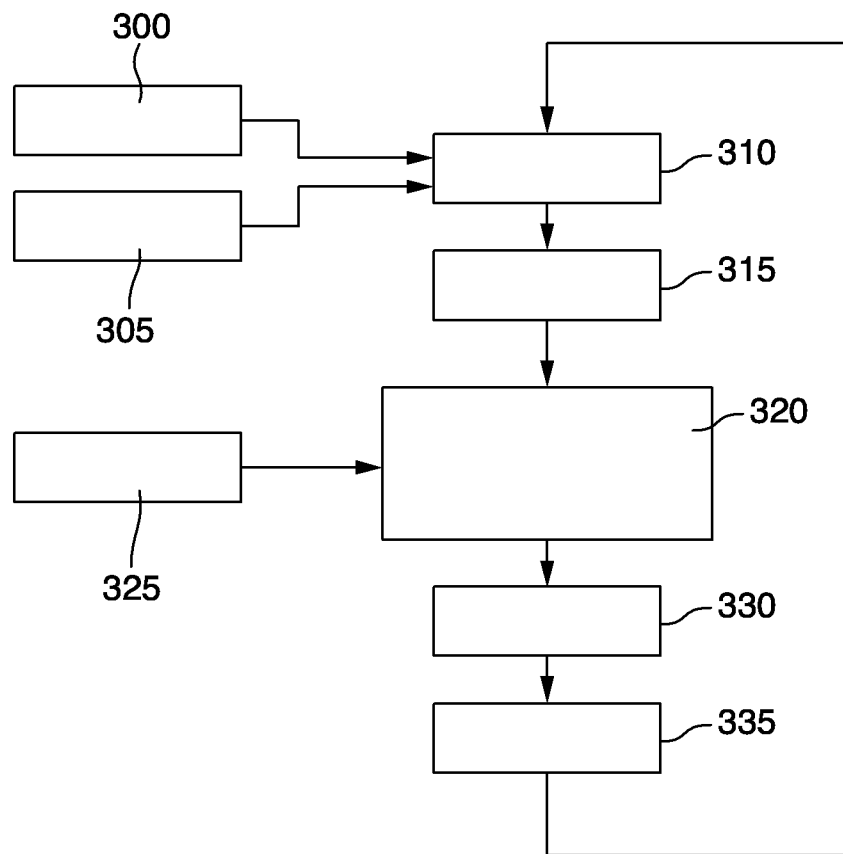


Fig. 3

