(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 128 275 A1**

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.02.2017 Bulletin 2017/06

(21) Application number: **15180131.3**

(22) Date of filing: **07.08.2015**

(51) Int Cl.:
F27B 7/38 *(2006.01)* ***B65G 23/00*** *(2006.01)*
F27B 7/42 *(2006.01)* ***F27D 15/02*** *(2006.01)*
F27D 19/00 *(2006.01)* ***F27D 21/00*** *(2006.01)*

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

(71) Applicant: **Alite GmbH**
31535 Neustadt (DE)

(72) Inventors:
- **Hammerich, Jörg**
31535 Neustadt (DE)
- **Deutgen, Martin**
31535 Schloss Neustadt (DE)
- **Hennemann, Peter**
31535 Schloss Neustadt (DE)

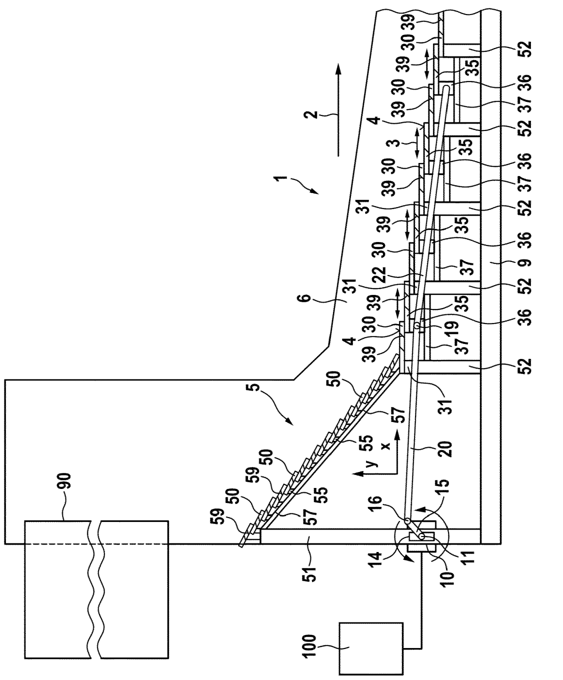
(74) Representative: **Jöstingmeier, Martin**
Lohr, Jöstingmeier & Partner
Junkersstraße 3
82178 Puchheim (DE)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) **CEMENT CLINKER COOLER GRATE**

(57) A cement clinker cooler grate 1 for cooling and conveying cement clinker in a forward direction 2 comprising a grate surface for supporting the clinker, which is conveyed by some reciprocating conveying means 35, e.g. a reciprocating row of grate plates 35, being arranged one besides of the other on a reciprocating cross beam 36, provides reduced installation, operation and maintenance costs if the actuator for driving the reciprocating conveying means 35 is an electric motor 10 being operably connected to the reciprocating conveying means 35 and if a controller 100 is connected to the electric motor 10 for controlling the rotational speed of the motor 10 as a function of the position and/or the direction of movement of the reciprocating conveying means 35.

Fig. 1



EP 3 128 275 A1

Description

Field of the invention

[0001] The invention relates to a cement clinker cooler grate for cooling and conveying cement clinker in a forward direction comprising a grate surface for supporting the clinker, which may be unloaded from a kiln onto said grate surface. The clinker is conveyed by some reciprocating conveying means, e.g. a reciprocating row of grate plates, being arranged one besides of the other on a reciprocating cross beam. The reciprocating conveying means is driven by an actuator being operably connected to the reciprocating conveying means for driving the reciprocating conveying means. The invention as well relates to a method for driving the reciprocating conveying means of a cement clinker cooler grate.

Description of the related art

[0002] In cement clinker manufacturing raw meal is burnt and sintered in a rotary kiln to thereby obtain cement clinker, briefly 'clinker' which may subsequently be further processed to obtain cement. The clinker is unloaded from said kiln via the so called clinker inlet distribution system, as well referred to as clinker distribution system, onto a conveyor grate floor of a clinker cooler, briefly 'cooler'. The clinker inlet distribution system often resembles a chute. On the grate floor, the clinker forms a layer, as well referred to as clinker bed. The height of the clinker bed is typically about 0.5m-0.7m. The clinker bed is cooled and transported (conveyed) in a forward direction to a clinker outlet of the cooler, e.g. via a crusher for further processing, e.g. milling. The construction of the grate floor is essential as on the one hand cooling air has to be inserted into the clinker bed via the grate floor and on the other hand clinker drop through the grate floor has to be avoided. In addition the clinker has to be transported and the grate floor must withstand the high clinker temperatures and the abrasion caused by moving the clinker over the grate floor.

[0003] These coolers have a grate surface with grate openings for injecting a cooling gas via the grate into the clinker residing on top of the grate. Further, these coolers have conveying means for conveying the clinker in said forward direction. There are multiple conveying systems, the most common systems come under one of the following categories:

- Reciprocating conveying means, i.e. a part of the grate and/or separate pushers move forth and back in an essentially linear oscillation, thereby conveying the clinker on top of the grate. The reciprocating movement is thus an oscillation of the reciprocating conveying means, wherein the oscillation may take place at least essentially parallel to the conveying direction and/or the grate surface. Such systems are disclosed e.g. in EP 2 843 342, DE 20 2006 012 333 U1, DE 10 2006 037 765 A1, US 8,397,654, EP 786637 A1 to name only a few.

- Drag-chain conveyors, i.e. systems based on conveying means that are moved forward above the grate surface and moved back to the kiln facing side of the grate below the grate. These systems mostly comprise chains to which the conveying means are attached (cf. EP 07 185 78 A2, Fig. 3).

- Belt conveyors or chain conveyors, examples are suggested e.g. in DE23 46 795 or DE1 985 673.

Summary of the invention

[0004] Here, we focus only on clinker coolers with the reciprocating conveying means. Presently, these reciprocating conveying means are driven by hydraulic cylinders. These enable to reliably and precisely drive the reciprocating conveying means and to provide the required high drive forces, which are depending on the size of the grate, but can easily reach 500kN or more.

[0005] The problem to be solved by the invention is to provide a clinker cooler with reciprocating conveying means that is easier to manufacture and easier to maintain and has lower operation expenses.

[0006] Solutions to the problem are described in the independent claims. The dependent claims relate to further improvements of the invention.

[0007] The cement clinker cooler grate enables conveying clinker or another bulk material in a conveying direction. The conveying direction or forward direction is directed from the clinker inlet, i.e. the kiln facing side of the clinker cooler to its clinker outlet. The cooler further comprises a conveyor grate, briefly 'grate', with an up facing surface for supporting the clinker. For example, the grate may comprise planks being arranged one besides of the other with their longitudinal direction in parallel to the conveying direction. At least one, preferably some of the planks may be movably supported to enable a reciprocating movement parallel to the conveying direction. In other words at least some of the planks can be moved forward and retracted afterwards. Conveying may occur for example according to the walking floor principle. In an alternative example the grate is a step grate, which comprises overlapping rows providing a stepped grate surface. These rows are often formed by grate plates being arranged transverse to the conveying direction e.g. on cross beams, wherein at least some of the grate plates are movably supported to enable a reciprocating movement of the respective grate plates. In the first example, the movable planks are reciprocating conveying means and in the second example, the movable grate elements are reciprocating conveying means. A further example for a reciprocating conveying means could be a cross bar being movably supported to reciprocate parallel to the conveying direction above a static grate surface. The reciprocating movement can be, but is not necessarily a linear movement. Some suspensions of reciprocating conveying means are pendulum suspensions providing a small vertical amplitude. Such movement is considered as 'quasi linear', i.e. almost linear. Briefly, reciprocating conveying means are not lowered, i.e. not moved downwards below the grate to enable retraction as it is the case for circulating conveying means of chain conveyors, drag-chain conveyors and belt conveyors.

[0008] The cooler comprises at least one actuator being operably connected to at least one reciprocating conveying means for driving the reciprocating conveying means. Different from the prior art grate coolers, the actuator comprises at least one electric motor with a rotor being mechanically connected to the reciprocating conveying means for driving said conveying means by a transmission. Here 'mechanically connected' means that the connection enables to transfer a rotation of the rotor into a reciprocating movement of at least one reciprocating conveying means, e.g. by a crank mechanism explained below. In this context hydraulic or pneumatic actuators are preferably not considered as a mechanical connection.

[0009] The grate cooler further comprises at least one controller being electrically connected to the electric motor for controlling the rotational speed of its rotor as a function of the position and/or direction of movement of the reciprocating conveying means. The controller thus preferably comprises at least one sensor for sensing the position of the at least one reciprocating conveying means and controls the rotational speed of the motor preferably in a closed loop as a function of said position.

[0010] The invention is based on the observation that hydraulic drives often suffer from leaking and the risk of oil contamination due to leaks. The solution of the invention, is much simpler, hydraulic lines, aggregates etc. are completely omitted. Further, hydraulic drives are mostly expensive, not only in acquisition but as well in maintenance and in particular in operation due to their low efficiency and the fact that the recent developments in power electronics enable to precisely control the speed of the reciprocating conveying means.

[0011] The above named 'mechanical connection', i.e. said transmission can be provided e.g. by at least one crank or eccentric shaft (both commonly referred to as 'crank'), being driven by the rotor, preferably via at least one gear. A connecting rod may be connected by a first pivot with a first pivot point to said crank and via a second pivot with a second pivot point to the at least one reciprocating conveying means. The latter connection is not necessarily a direct connection, for example the reciprocating conveying means may be connected to the connection rod via some force transmitting means, e.g. a drive frame coupling the connection rod to said at least one reciprocating conveying means or a cross bar supporting the reciprocating conveying means.

[0012] The first and second pivots each have a pivot point or a pivot axis, briefly commonly referred to as first or second pivot point, respectively.

[0013] For example two or more motors may be connected to a drive shaft. For example each motor may drive a reduction gear with an output shaft which is coupled to the drive shaft. Said drive shaft drives at least one, preferably two or more cranks. Said cranks are coupled each by at least one connection rod to at least one reciprocating conveying means. Briefly, two or more motors may commonly drive a drive shaft which is connected to two or more crank drives. This design enhances longevity as the load is shared between multiple redundant parts. Alternatively the load, i.e. the maximum power that can be coupled to the reciprocating conveying means can be enhanced.

[0014] In any of these examples the mechanical connection is thus a transmission for converting the rotation provided by the motor into a linear movement of the reciprocating conveying means. Preferably the movement is periodically, i.e. $\alpha(t) = \alpha(t + T)$ wherein $\alpha(t)$ is the angular position of the crank arm at a time t and T is the length of the period, or briefly period. T can be varied to augment the conveying speed of the clinker: decreasing the period T will augment the clinker speed and increasing T will slow the clinker down. Only for simplicity, it is assumed that T is constant, as the conveying speed is adjusted in response to changes of the clinker production rate. This assumption typically holds true for time scales being much longer than the period T.

[0015] The sensor can be e.g. a sensor measuring the angular position α of the crank arm, i.e. the direction of the vector pointing from the rotational axis of the crank to the pivot point of the first pivot.

[0016] Preferably, the rotational direction of the motor is constant. This simplifies the controller's electronics and enhances the longevity of the mechanical components of the transmission.

[0017] Preferably, the first pivot and/or at least a part of said connecting rod are positioned below a clinker inlet distribution chute. This enables to arrange the connecting rod's longitudinal axis at least approximately parallel (±30°) to the direction of movement of the reciprocating conveying means. Of course the connecting rod's inclination changes when the crank rotates, but here the mean inclination shall define the rod's longitudinal axis. In other words, the rod's inclination is to be measured when the crank arm's longitudinal axis is parallel to the moving direction of the reciprocating conveying means. This essentially parallel orientation of the connection rod and the conveying direction enables to keep the vertical components of the drive force low and thus the additional load to be compensated, e.g. by a static frame supporting the grate. Further, positioning the connecting rod below the chute, enables to use a comparatively long connection rod, further reducing the vertical components of the drive force to only a few percent of the total force provided to the reciprocating conveying means. The connection rod can be even longer, if the crank and thus the pivot are positioned in the extension of the clinker inlet distribution system, e.g. between the clinker inlet distribution system and a base supporting bearings for the kiln. Accordingly, the distance d_{pp} between the first pivot point and the second pivot point is at least 10 times bigger than the distance d_{pa} between the first pivot's pivot point and the rotational axis of the crank, i.e. $d_{pp} \geq 10 \cdot d_{pa}$ or even better $d_{pp} \geq 20 \cdot d_{pa}$, preferably $d_{pp} \geq 30 \cdot d_{pa}$.or even $d_{pp} \geq 50 \cdot d_{pa}$.

[0018] The grate is typically supported on a base by a static frame below said grate. Said frame may as well support the electric motor and/or a gear coupling the motor with the crank or a connection rod, or in other words, the electric motor and/or the gear may be attached to said frame. This mounting point has the advantage that the counter action of the driving force for driving the reciprocating conveying means is directly absorbed by the frame.

[0019] For example the motor may drive the crank via a reduction gear with an output shaft. The motor may be attached to and be supported by the gear, e.g. its housing. The output shaft is preferably coupled by a releasable coupling to the crank, e.g. via a drive shaft. Thus the crank and/or the drive shaft, respectively, may support the gear (and thus the motor as well) vertically, i.e. their weight. The frame may comprise a torque support supporting the gear. For example, a beam of the frame may comprise a torque support blocking a rotation of the gear housing in at least one direction. For example at least one flange of a beam may provide said torque support. Decoupling of torque and weight support enables to easily replace a worn gear by simply removing the gear from the drive shaft or crank, respectively and replacing it by pushing a new gear onto the drive shaft or crank. In the simplest case, the output shaft is a hollow shaft being form fittingly received by the corresponding end of the drive shaft (or vice versa). Thus, the releasable coupling enables to simply pull the gear off the drive shaft and to connect a new one by literally pushing it on the drive shaft. The frame may of course comprise a bearing supporting the crank and/or the drive shaft and thus the weight of the gear (and the motor) via said bearing. But in any case weight and torque support are obtained differently, enabling to repair the grate in short term.

[0020] In the simplest case, the rotor rotates at a constant rotational speed. In this case the speed of the conveying means is sinusoidal. This sinusoidal speed of the conveying means already provides advantages with respect to the longevity of the bearings, because the peaks in the force transmitted between the motor and the reciprocating conveying means are reduced if compared with the prior art hydraulic actuated reciprocating conveying means.

[0021] Preferably, the controller is configured to monitor at least the direction of movement of the reciprocating conveying means and to change the rotational speed of the motor as a function of the direction of movement of the reciprocating conveying means. For example, the controller may be configured to speed up the motor, i.e. to augment the rotational speed of its rotor when retracting the conveying means and to slow the motor down (i.e. to reduce the rotational speed) when pushing the conveying means forwards. This results in conveying means that are retracted at a faster speed than being pushed forward as the clinker shall 'stick' to the conveying means when pushed forwards and slide over the conveying means when it is retracted. But different to the prior art, there is no need to provide a complex control of flow valves and no wear of such valves for controlling the plunger's movement.

[0022] For example, the controller may be configured to vary the rotational speed of the motor as a function of the angular position α of the crank arm between preferably at least two constant values: a first value $\omega_{f,const}$ defining a first absolute value of a first constant rotational speed of the motor during the forward movement of reciprocating conveying means and a second value $\omega_{r,const}$ defining a second absolute value of a constant rotational speed of the motor during the retraction of the reciprocating conveying means. At least one of said values $\omega_{f,const}$ $\omega_{r,const}$ is preferably maintained for a significant period of the forward or backward movement, respectively, of the reciprocating conveying means. Mathematically speaking

$$\frac{d}{d\alpha}\omega(\alpha) = 0 \text{ and } |\omega(\alpha)| = \omega_{f,const}, \forall a | \alpha_{f,1} < \alpha < \alpha_{f,2}$$

and/or

$$\frac{d}{d\alpha}\omega(\alpha) = 0 \text{ and } |\omega(\alpha)| = \omega_{r,const}, \forall a | \alpha_{r,1} < \alpha < \alpha_{r,2}$$

wherein $\alpha_{f,1}$, $\alpha_{f,2}$ $\alpha_{r,1}$ $\alpha_{r,2}$ are each selected angular positions of the crank arm corresponding to a forward movement (indicated by index f) or retraction (indicated by index r) of the reciprocating conveying means between the two dead centers. In the vicinity of the dead centers the corresponding ramp up or ramp down of the rotational speed may take place.

[0023] The rotational speed of the motor $\omega_{f,const}$ during the forward movement of reciprocating conveying means is preferably smaller than the corresponding rotational speed during retraction $\omega_{r,const}$, i.e. $\omega_{f,const} < \omega_{r,const}$, more preferred: $1.5 \cdot \omega_{f,const} < \omega_{r,const}$, or better: $2 \cdot \omega_{f,const} < \omega_{r,const}$ or even $3 \cdot \omega_{f,const} < \omega_{r,const}$. Astonishingly, the force F_r required for retracting the conveying means is essentially constant $(\frac{dF_r}{d\omega_r} \approx 0)$, but the force F_f for driving the reciprocating conveying means forward increases with ω_f. Thus speeding up the retraction speed does not (significantly) increase the force to be transmitted by the transmission and thus not the maintenance costs (strictly per cycle), but it enables to shorten the period T of a cycle.

[0024] Accordingly, within reasonable limits, $\omega_{f,const}$ can be minimized and $\omega_{r,const}$ can be maximized for a given required conveying speed of the clinker to thereby reduce the mean load of the transmission. In other words, upon a request for augmenting or reducing the clinker conveying speed preferably only $\omega_{f,const}$ is augmented or reduced, respectively as $\omega_{r,const}$ should be kept at least almost constant close to its designed maximum, as it should always be as large as reasonable. Only to define borders, the change in $\omega_{r,const}$ for change of the conveying speed $\Delta\omega_{r,const}$ is preferably smaller than 50% of the corresponding change in $\Delta\omega_{f,const}$ when changing the conveying speed, i.e. $\Delta\omega_{r,const} \leq 0.5 \cdot \Delta\omega_{f,const}$, preferably $\Delta\omega_{r,const} \leq 0.25 \cdot \Delta\omega_{f,const}$ or even better $\Delta\omega_{r,const} \leq 0.1 \cdot \Delta\omega_{f,const}$.

[0025] Further, the controller is preferably configured to restrict the torque M provided by the motor to the crank arm when the crank arm passes its dead centers (at least one of the two dead centers) to a preselected value M_s. This preselected value can be e.g. 150% of the torque value $M_{f,max}$ or $M_{r,max}$ required for pushing the reciprocating conveying means in the forward or rearward direction, respectively, with maximum forward or backward (respectively) speed during a cycle i.e., $M_s \leq 1.5 \cdot M_{f,max}$ or $M_s \leq 1.5 \cdot M_{r,max}$, $M_s \leq M_{f,max}$ or $M_s \leq M_{r,max}$, preferably $M_s \leq 0.8 \cdot M_{f,max}$ or $M_s \leq 0.8 \cdot M_{r,max}$ or even smaller. When passing the dead centers, the direction of movement of the reciprocating conveying means is inverted. This inversion provides a high load or stress in particular to the bearings, e.g. said at least one pivot; restricting the torque reduces the speed of the motor and thus of the reciprocation conveying means when passing the dead centers, but avoids load peaks and thereby reduces maintenance costs.

[0026] As well, the controller may preferably be configured to control the rotational speed of the motor and thus of the crank arm to ramp up the forward speed v_f of the reciprocating conveying means to a maximum value $v_{f,max}$ and to maintain this maximum value $v_{f,max}$ until the reciprocating conveying means is to be slowed down ('ramp down') prior to retracting the respective reciprocating conveying means. Thus here, the motor's rotational speed is controlled to compensate for a nonlinear transmission. In the above example of the crank drive, the controller may thus compensate the sinusoidal relationship between the speed of the conveying means and the crank arm's angular position.

[0027] The ramp up of the forward speed is preferably at least essentially linear, or has at least a linear section. Under the assumption that the coupling between the conveying means and the clinker on top of the grate is constant for the corresponding speed of the reciprocating conveying means this results in a constant load to the bearings like e.g. said pivots, during ramp up and thus reduced maintenance costs.

[0028] The ramp down of the at least one conveying means' forward speed is preferably steeper than the ramp up of the forward speed. Here 'steeper', refers to the absolute value of the mean slope. A very simple measure is the time for ramp up and the time for ramp down: The ramp up time of the forward speed is preferably bigger than the ramp down time of the forward speed.

[0029] Retraction of the conveying means may be controlled by the controller in a similar manner. However, the absolute value of the maximum retraction speed $v_{r,max}$ is preferably higher than the absolute value of maximum forward speed $v_{f,max}$, e.g. $1.5 \cdot v_{f,max} \leq V_{r,max}$ even more preferred $2 \cdot v_{f,max} \leq v_{r,max}$ or even $3 \cdot v_{f,max} \leq v_{r,max}$. Further, the relative amount of time during retraction where $v_{r,max}$ is maintained is preferably smaller that the relative amount of time where $v_{f,maX}$ is maintained, i.e. $t_{r,max}/t_{r,total} < t_{f,max}/t_{f,total}$, wherein the $t_{r,max}$ is the absolute time where the $v_{r,max}$ is maintained, $t_{r,total}$ is the duration for retracting of the reciprocating conveying means, $t_{f,max}$ is the absolute time where the $v_{f,max}$ is maintained and $t_{f,total}$ is the duration of the forward movement. Neglecting eventual waiting times at the dead centers, the period T of a complete cycle is $T = t_{total} = t_{f,total} + t_{r,total}$. In step grate coolers the waiting time is preferably very small (zero or close to zero). In walking floor concepts, the waiting time makes a significant portion of a complete period, i.e. $T = t_{f,total} + t_{r,total} + t_d$, where t_d is the delay (waiting time).

[0030] This can be realized very efficiently by controlling the crank's angular speed as a function of its angular position. For example a method for controlling the velocity v(t) of at least one reciprocating conveying means of a cement clinker cooler grate may comprise actuating the reciprocating conveying means by powering an electric motor. As already explained above, said electric motor may have a rotor being coupled via at least a crank and a connection rod to the least one reciprocating conveying means. Of course there may be pivots connecting the crank and the connection rod and the connection rod and the conveying means as explained above. The rotational speed of the motor may be controlled to linearize the movement of the conveying means. For example, the rotational speed may be controlled as a function of the crank's spatial orientation, i.e. its angular position. In a preferred embodiment the motor is coupled via a reduction gear to a drive shaft. The drive shaft drives and optionally supports the crank.

[0031] In a particularly preferred example, a sinusoidal movement of the crank in the direction of the reciprocating movement is compensated at least partially. The displacement of the pivot point or pivot axis (briefly simply 'pivot point') in the reciprocating direction of the reciprocating conveying means is sinusoidal, i.e. when orthogonally projecting the pivot point connecting the crank and the connection rod onto a plane which is parallel to the direction of the reciprocating movement, the displacement $\Delta x(\alpha)$ in the x direction which is supposed to be the direction of the reciprocating movement of the reciprocating conveying means, is sinusoidal, i.e. $\Delta x(\alpha)=l\cdot\cos(\alpha)$, wherein α is the angle of the crank arm and l the length of the crank arm. Accordingly, the velocity of reciprocating conveying means can be set by defining $\dot{\alpha}=\frac{d\alpha}{dt}=-\frac{\dot{\Delta x}(\alpha)}{l\cdot\sin(\alpha)}$, thus it is possible to maintain a constant velocity $v(\alpha(t))(=\dot{\Delta x}=\frac{\mathrm{d}\Delta x(\alpha)}{\mathrm{dt}})$ of movement of the reciprocating conveying means by adjusting the angular velocity $\dot{\alpha}(\alpha)$. Of course this is possible only for those angles α, where $1/\sin(\alpha)$ does not diverge, which is at the dead centers. Thus, between the dead centers, the velocity of the reciprocating conveying means can be adjusted to almost any reasonable value. A simple controller, controlling the rotational speed of the motor's rotor which drives the crank arm, preferably with a fixed reduction ratio due to some reduction gear, thus enables to reciprocate the reciprocating conveying means with almost any velocity profile and in particular to compensate the sinusoidal movement of the pivot point.

[0032] Preferably, the absolute value of the slope of the velocity $v(\mathrm{t})$ $(\mathrm{i.e.}\ \frac{d}{dt}v(\mathrm{t}))$ of the reciprocating conveying means has at least a local minimum when the velocity *v*(t) changes its sign.

[0033] Further, as explained above, it is advantageous, if the maximum angular speed of the crank when retracting the at least one reciprocating conveying means is bigger than the maximum angular speed of the crank when pushing said at least one reciprocating conveying means. This can as well be obtained by adjusting the rotational speed of the motor accordingly.

[0034] Although not always explicitly stated, all of the above explained examples for the movement of the reciprocating conveying means and the motor's rotational speed may be controlled by the controller. Further, the optional reduction from the motor's rpm to the drive shaft rpm is supposed to be fixed, thus $\omega(\alpha)=c\cdot\frac{d}{dt}\alpha(t),$ wherein c is a constant. Controlling the motor's rotational speed thus is equivalent to controlling the crank's rotational speed and thus its angular position.

Description of Drawings

[0035] In the following the invention will be described by way of example, without limitation of the general inventive concept, on examples of embodiment with reference to the drawings.

Figure 1 is a schematic side view of a partially assembled cooling section of a cement clinker line,

Figure 2 shows a cross section of an actuator unit,

Figure 3 shows a cross section of a further actuator unit,

Figure 4 shows a velocity profile of reciprocating conveying means, and

Figure 5 shows a further velocity profile of reciprocating conveying means.

[0036] In Figure 1 a preferred embodiment according to the invention is shown: Cement clinker may be unloaded from a kiln 90 onto a clinker inlet distribution system 5. In this example, the clinker distribution system 5 is a chute of overlapping grate plates 50 being mounted one besides of the other on cross beams 55. The cross beams may be supported by at least one girder 57. Other types of clinker distribution systems may be used as well. Preferably, the grate plates 50 or at least some of them provide cooling slits 59 for blowing a cooling gas from below the grate plates 50 into the clinker on top of them. From this clinker inlet distribution system, the clinker is supplied to a cement clinker cooler grate 1, briefly 'grate'.

[0037] This grate 1 comprises grate plates 30, 35 on cross beams 31, 36. Typically multiple grate plates 30, 35 are arranged one besides of the other on a cross beam 31, 36. A row of grate plates 30, 35 overlaps the next row (referring to the conveying direction 2) thereby providing a step grate with a grate surface 4. At least one of the grate plates 30, 35 is movably supported, enabling a reciprocating movement as indicated by double headed arrows 3. In this example the corresponding cross beams 36 are movably supported on longitudinal extending guide rails 37 or girders 37, but other solutions for movably supporting the reciprocating cross bars 36 are as well possible. Only to ease understanding, the movable support is simplified as slide bearing, other types of movable supporting the reciprocating conveying means are possible as well, for example the pendulum support as disclosed in DE 101 18 440 or the ball bearing support suggested in DE 1841381 to name only two. An actuator is provided for pushing the movable grate plates 35 forward and to retract them afterwards. When pushing the movable grate plates 35 forwards, the clinker is pushed in the forward direction 2. Subsequently, the grate plates 35 are retracted and the front plates of the respective (previous) overlapping fixed grate plates 30 inhibit the clinker bed to be retracted as well. The movable grate plates 35 thus slide below the clinker bed when retracted. The movable grate plates 35 are thus reciprocating conveying means.

[0038] The actuator comprises an electric motor 10 driving a drive shaft 11, e.g. via a reduction gear. The stator of the electric motor 10 and the optional reduction gear are preferably mounted to the frame supporting the clinker cooler on its base 9. The frame may comprise vertical beams ('poles') 51, 52, girders 37, 57, cross beams 55, 31 and the like.

[0039] The drive shaft 11 is mechanically coupled to a crank arm 15. The crank arm 15 is connected via pivot 16 with at least one connection rod 20. The at least one connection rod 20 is attached as well to a reciprocating conveying means 35. In this example the reciprocating conveying means 35 is connected to the connection rod 20 via the movably supported cross beam 36 and a further pivot 19. An optional transmission rod 22 may connect further reciprocating conveying means 35. A transmission rod 22, may e.g. be a longitudinal beam of a movably supported drive frame, to which the reciprocating cross beams 36 are mounted and which is movably supported with respect to the base and thus the static grate plates 30. Alternatively, each conveying means 35 may be driven by a separate actuator. As further alternative the conveying means 35 may be grouped by at least one transmission rod 22 (and/or a movable drive frame) and each group may be driven by at least one separate actuator. In any case, when the motor 10 drives the crank arm 15, the connecting rod 20 converts the circular motion of the drive shaft 11 into a linear reciprocating movement of the corresponding reciprocating conveying means 35.

[0040] As can be seen, the actuator, i.e. the motor 10, the optional reduction gear which is here included in the motor 10 and the crank arm 15 are positioned below the clinker inlet distribution system 5. Thereby, the actuator is easily accessible for maintenance and the length of the connection rod 20 may be augmented. Thereby, the vertical components of the force for driving the crank arm that has to be compensated by the frame is reduced. The motor could be displaced, but the crank arm should be positioned as far as possible from the pivot 19, to thereby obtain small pivot angles of the connection rod 20 .

[0041] The electric motor 10 is controlled by a controller 100. The controller 100 controls the rotational speed of the crank arm 15 as function of its angular position, which may be measured by a corresponding sensor. The sensor is preferably integrated in the motor, a motor housing, a gear and/or a gear housing, to thereby protect the sensor. Alternatively at least one sensor may be installed to determine the actual position x(t) of the reciprocating conveying means and to provide it to the controller 100. Relevant for controlling the rotational speed are two factors, the absolute force exerted to the pivots and other bearings and the speed v(t) of the reciprocating conveying means 35. The absolute force is critical at the dead centers of the crank arm 15, as a reversal of the direction of the reciprocating grate elements occurs.

[0042] Fig. 2 shows a preferred example for mounting an actuator. The actuator comprises a motor 10 with a rotor 101. The rotor 101 drives an input shaft 122 of a reduction gear 12. Here, but only as example, the rotor 101 is coupled via a worm drive to the input shaft 122. The input shaft 122 is connected via a planetary gear to a drive shaft 11. The drive shaft 11 is coupled to a crank 15, which is coupled via a first piviot 16 to a connection rod 20 as indicated in Fig. 1. The drive shaft 11 may be connected to at least one further crank 15 and/or at least a second motor 10 as indicated by the dashed line (cf. Fig. 3). The gear 12 has a gear housing 121. The gear housing 121 is supported by a vertical beam 51 (cf. Fig. 1) of the frame supporting the clinker inlet distribution. Alternatively, the gear could be mounted to a vertical beam 52 supporting the clinker cooler grate. In this example, the vertical beam is an I-beam as well referred to as H-beam due to its H-shaped cross section, i.e. a beam with two parallel flanges being connected by a web. Other beams could be used instead. As shown, the drive shaft 11 may extend through a hole in the vertical beam 51 and/or may be supported by an optional bearing 14 being connected to the beam 51 as well and enabling rotation of the drive shaft 11. In this example the bearing 14 is a plain bearing with a bushing 141, but roller bearings may be used as well. As shown here, the gear 12 and the drive shaft bearing 14 may be attached at opposed sides of the beam 51. Alternatively, the gear can be vertically supported by the drive shaft 11. The beam 51 may provide only a torque support to the gear. This enables to easily replace a defective gear by simply removing the gear from the drive shaft and replacing it by 'pushing' a new gear 12 onto the drive shaft 11. In this case the gear may have a separate output shaft being coupled by a releasable coupling to the drive shaft 11 as explained above. For example, the drive shaft 11 is a hollow shaft being form fittingly received by the output shaft's 11 end (or vice versa). This enables to simply remove the gear in case of failure and to literally push a new one on the drive shaft 11. The weight of the gear is supported by the drive shaft 11, which in turn is supported by the drive shaft bearing 14. The drive shaft bearing 14 may of course be attached to the same beam as the torque support of the gear 12.

[0043] Fig. 3 shows two coupled actuators. The actuators are similar to the actuator as explained with respect to Fig.

2. Accordingly, the same or similar parts have identical reference numerals. The embodiment of Fig. 3 has two motors 10, each being coupled by a gear to a common drive shaft 11. The drive shaft 11 has two cranks 15, oriented in parallel. Each crank 15 is connected via a (first) pivot 16 to a connection rod, which is connected to at least one reciprocating conveying means, e.g. as shown in Fig. 1

[0044] Fig. 4 is a diagram showing the motor's rotational speed (rpm) on the right ordinate and the absolute value of the speed v(t) of the reciprocating conveying means on the left ordinate. The abscissa is the time axis and T indicates the period T. The diagram shows an example relation for a motor driving a crank drive via a reduction gear as shown e.g. in Fig. 1 to Fig. 3. At t_o=0 the rpm of the motor (dashed line) is reduced to a first constant value $\omega_{f,const}$ (at t_1). This constant value is maintained until t_2. At t_2 the crank reaches its dead center, and the rotational speed is maximized to reach a second constant value $\omega_{r,const}$ at t_3 which is maintained as long as the reciprocating conveying means is retracted, i.e. until the end of the period T. The solid line indicates the corresponding speed of the reciprocating conveying means. As can be seen, between t_1 and t_2 as well as between t_3 and T, i.e. when the rotational speed $\omega(t)$ is constant, the speed v(t) is sinusoidal. Further, as $\omega_{r,const} > \omega_{f,const}$ the retraction time T-t_2 is shorter than the time of the forward movement t_2-t_0.

[0045] A further example of a movement profile of the reciprocating conveying means 35 is depicted in Fig. 5. The abscissa is the time axis and the ordinate shows the velocity v(t) of the reciprocating conveying means 35 along the direction indicated by the double headed arrow 3, wherein a positive velocity points away from the kiln 90. A cycle starts with a gently increasing velocity v(t) ($t_0 \leq t < t_g$) to slightly increase the force to be transmitted by the pivots. Next the velocity increases faster ($t_g \leq t < t_a$). For example, the acceleration may be constant in this section, but preferably the force to be transmitted by the pivots 19 is kept constant. The speed of the reciprocating conveying means 35 may reach a maximum forward speed $v_{f,max}$, that is reduced when reaching the forward dead center point at t_f. Slowing down may be accomplished much faster, as the force transmitted between the crank 15 and the transmission rod 20 simply needs to be reduced, e.g. to zero. In this case the motor idles with a decreasing rotational speed that corresponds to the deceleration of conveying means 35 due to the clinker on top of the grate, friction and the like in case the motor would be decoupled from the respective reciprocating conveying means. Accordingly the pivots 16, 19 are so to speak unloaded during deceleration at least for a period of time during deceleration. The subsequent acceleration in the inverse direction follows the same principle as the acceleration in the forward direction, but the maximum retraction speed $v_{r,max}$ is preferably bigger than the maximum forward speed $v_{f,max}$. Preferably, the absolute value of the maximum acceleration in the rearward direction, i.e. when retracting the reciprocating conveying means 35, is bigger than the absolute value of the maximum acceleration in the forward direction, i.e. when pushing the reciprocating conveying means 35 forward. The effect is that the transition to slide friction between the retracted conveying means 35 and the clinker residing on top of it takes place quickly. When the reciprocating conveying means 35 reaches its rearward dead center, it is slowed down to zero at v(T). At t=T the cycle may start again, i.e. v(t)=v(t+T). In some embodiments the cycle may restart after a delay t_d. As can be seen from the Figure, when approaching a dead center, the absolute value of the speed reduces at a very high rate, i.e. the absolute value of the deceleration when approaching a dead center is preferably bigger than the absolute value for the acceleration away from said dead center.

[0046] The invention was explained above with respect to a step grate cooler, but the transmission of the rotation of a motor driving the drive shaft and the considerations with respect to the velocity profile of the reciprocating conveying means can be transferred as well to grates of planks being arranged one besides of the other in parallel to the conveying direction, wherein at least some of said planks are movably supported to enable a reciprocating movement of said planks. These movable planks can be driven by a similar or the same transmission (electric motor, optional reduction gear, crank and connection rod) as explained above and thus become reciprocating conveying means. Dimensioning has to be adapted, of course. The controller and the methods for controlling the motor(s) can be used as well.

List of reference numerals

[0047]

1	cement clinker cooler grate, briefly 'grate'
2	conveying direction / forward direction
3	double headed arrow indicating reciprocating movement
4	grate surface
5	clinker distribution system
6	side wall
9	base
10	electric motor (with optional reduction gear)
11	drive shaft
12	gear / reduction gear
14	drive shaft bearing

15	crank / crank arm
16	pivot
19	pivot
20	connection rod
22	transmission rod
30	grate plates
31	cross bars (static)
35	movably supported grate plates / reciprocating conveying means
36	cross bars (reciprocating, movably supported)
37	guide rails
39	cooling slits
50	grate plates
51	vertical beam
52	vertical beam
55	cross beams
57	girder
59	cooling slits
90	kiln
100	controller
101	rotor
121	gear housing
122	input shaft
123	gear wheel
124	gear wheel (e.g. sun gear)
125	gear wheel (e.g. planetary gear)
126	gear wheel (e.g. gear ring)
141	bushing of drive shaft bearing
151	pivot axle

Claims

1. Cement clinker cooler grate (1) for cooling and conveying clinker in a forward direction comprising at least:

    - a grate surface (4) for supporting the clinker,
    - at least one reciprocating conveying means (35),
    - an actuator being operably connected to the reciprocating conveying means (35) for driving the reciprocating conveying means (35), **characterized in, that**

    the actuator comprises at least one electric motor (10) being operably connected to the reciprocating conveying means (35) for driving said conveying means (35), and
    a controller (100) being connected to the electric motor (10) for controlling the rotational speed of the motor (10) as a function of the position and/or the direction of movement of the reciprocating conveying means (35).

2. The cement clinker cooler grate (1) of claim 1,
    characterized in, that
    the motor drives at least one crank (15) to which a connecting rod (20) is attached by at least one first pivot (16), said connecting rod (20) being connected to the reciprocating conveying means (35) or a support thereof by a least a second pivot (19).

3. The cement clinker cooler grate (1) of claim 2,
    characterized in, that
    the pivot (16) of said connecting rod (20) is positioned below a clinker inlet distribution system (5) or in the extension of the clinker inlet distribution system (5) and that said connecting rod (20) extends parallel (±30°) to the conveying direction (2).

4. The cement clinker cooler grate of claim 2 or 3
    characterized in that

the distance d_{pp} between the first and second pivots' (16, 19) pivot points is at least 10 times bigger than the distance d_{pa} between the first pivot's (16) pivot point and the rotational axis of the crank (15), i.e. $d_{pp} \geq 10 \cdot d_{pa}$.

5. The cement clinker cooler grate (1) of one of the preceding claims,
characterized in, that
the grate (1) providing the grate surface (4) is supported on a base (9) by a frame (37, 51, 52, 55) below said grate (1) and **in that** the electric motor (10) is attached to said frame (37, 51, 52, 55).

6. The cement clinker cooler grate (1) of one of the preceding claims,
characterized in, that
the rotational speed of the motor (10) is lower when moving the reciprocating conveying means (35) in the forward direction (2) than when retracting it.

7. The cement clinker cooler grate (1) of one of the preceding claims,
characterized in, that
the cement clinker cooler grate (1) comprises at least two reciprocating conveying means (35), being connected to each other by at least one transmission rod (22) coupling the at least two reciprocating conveying means (35) at a constant distance.

8. The cement clinker cooler grate (1) of claim 6,
characterized in that
transmission rod (22) is integrated in a movable drive frame.

9. The cement clinker cooler grate (1) of one of claims 1 to 8
characterized in that
the actuator comprises a drive shaft (11) with at least two cranks (15), which are each connected via a connection rod (20) to at least one reciprocating conveying means (35).

10. The cement clinker cooler grate (1) of one of claims 1 to 9,
characterized in that
at least one electric motor (10) is coupled via at least one reduction gear (12) to the drive shaft (11).

11. The cement clinker cooler grate (1) of one of claims 1 to 10
characterized in that
the motor (10) and/or the gear (12) and/or a bearing (14) of the crank (15) are supported by at least one vertical beam (51, 52) supporting a grate floor of the clinker cooler and/or a clinker inlet distribution system.

12. Method for controlling the velocity v(t) of at least one reciprocating conveying means (35) of a cement clinker cooler grate (1),
characterized in that it comprises at least
actuating the reciprocating conveying means (35) by powering an electric motor (10), wherein the reciprocating conveying means (35) are coupled to said motor (10) at least by a crank arm (15) and a connection rod (20) for linearizing the rotational movement of the motor (10),
and
controlling the rotational speed of the motor (10) as a function of the crank (15) arm's angular position.

13. The method of claim 12,
characterized in that
a sinusoidal movement of the crank (15) in the direction of the reciprocating movement (3) is compensated by said controller (100) to obtain a velocity profile of the reciprocating grate element (35) having at least one section where a non-zero velocity is constant and/or the rotational speed of the motor is varied as a function of the angular position α of the crank arm between at least two constant values ($\omega_{r,max}$, $\omega_{f,max}$).

14. The method of claim 12 or 13,
characterized in that
the absolute value of slope of the velocity v(t) has at least a local minimum when the velocity v(t) changes its sign.

15. The method of one of claims 12 to 14,

characterized in that
the maximum angular speed of the crank (15) when retracting the at least one reciprocating conveying means (35) is bigger than the maximum angular speed of the crank (15) when pushing said at least one reciprocating conveying means (35) forward.

Amended claims in accordance with Rule 137(2) EPC.

1. Cement clinker cooler grate (1) for cooling and conveying clinker in a forward direction comprising at least:

    - a grate surface (4) for supporting the clinker,
    - at least one reciprocating conveying means (35),
    - an actuator being operably connected to the reciprocating conveying means (35) for driving the reciprocating conveying means (35),

    wherein
    the actuator comprises at least one electric motor (10) being operably connected to the reciprocating conveying means (35) for driving said conveying means (35),
    characterized in that
    the actuator further comprises a controller (100) being connected to the electric motor (10) for controlling the rotational speed of the motor (10) as a function of the position and/or the direction of movement of the reciprocating conveying means (35).

2. The cement clinker cooler grate (1) of claim 1,
    characterized in, that
    the motor drives at least one crank (15) to which a connecting rod (20) is attached by at least one first pivot (16), said connecting rod (20) being connected to the reciprocating conveying means (35) or a support thereof by a least a second pivot (19).

3. The cement clinker cooler grate (1) of claim 2,
    characterized in, that
    the pivot (16) of said connecting rod (20) is positioned below a clinker inlet distribution system (5) or in the extension of the clinker inlet distribution system (5) and that said connecting rod (20) extends parallel (±30°) to the conveying direction (2).

4. The cement clinker cooler grate of claim 2 or 3
    characterized in that
    the distance d_{pp} between the first and second pivots' (16, 19) pivot points is at least 10 times bigger than the distance d_{pa} between the first pivot's (16) pivot point and the rotational axis of the crank (15), i.e. $d_{pp} \geq 10 \cdot d_{pa}$.

5. The cement clinker cooler grate (1) of one of the preceding claims,
    characterized in, that
    the grate (1) providing the grate surface (4) is supported on a base (9) by a frame (37, 51, 52, 55) below said grate (1) and **in that** the electric motor (10) is attached to said frame (37, 51, 52, 55).

6. The cement clinker cooler grate (1) of one of the preceding claims,
    characterized in, that
    the rotational speed of the motor (10) is lower when moving the reciprocating conveying means (35) in the forward direction (2) than when retracting it.

7. The cement clinker cooler grate (1) of one of the preceding claims,
    characterized in, that
    the cement clinker cooler grate (1) comprises at least two reciprocating conveying means (35), being connected to each other by at least one transmission rod (22) coupling the at least two reciprocating conveying means (35) at a constant distance.

8. The cement clinker cooler grate (1) of claim 6,
    characterized in that

transmission rod (22) is integrated in a movable drive frame.

9. The cement clinker cooler grate (1) of one of claims 1 to 8
characterized in that
the actuator comprises a drive shaft (11) with at least two cranks (15), which are each connected via a connection rod (20) to at least one reciprocating conveying means (35).

10. The cement clinker cooler grate (1) of one of claims 1 to 9,
characterized in that
at least one electric motor (10) is coupled via at least one reduction gear (12) to the drive shaft (11).

11. The cement clinker cooler grate (1) of one of claims 1 to 10
characterized in that
the motor (10) and/or the gear (12) and/or a bearing (14) of the crank (15) are supported by at least one vertical beam (51, 52) supporting a grate floor of the clinker cooler and/or a clinker inlet distribution system.

12. Method for controlling the velocity v(t) of at least one reciprocating conveying means (35) of a cement clinker cooler grate (1), comprising at least actuating the reciprocating conveying means (35) by powering an electric motor (10), wherein the reciprocating conveying means (35) are coupled to said motor (10) at least by a crank arm (15) and a connection rod (20) for linearizing the rotational movement of the motor (10),
characterized in that
it further comprises controlling the rotational speed of the motor (10) as a function of the crank (15) arm's angular position.

13. The method of claim 12,
characterized in that
a sinusoidal movement of the crank (15) in the direction of the reciprocating movement (3) is compensated by said controller (100) to obtain a velocity profile of the reciprocating grate element (35) having at least one section where a non-zero velocity is constant and/or the rotational speed of the motor is varied as a function of the angular position a of the crank arm between at least two constant values ($\omega_{r,max}$, $\omega_{f,max}$).

14. The method of claim 12 or 13,
characterized in that
the absolute value of slope of the velocity v(t) has at least a local minimum when the velocity v(t) changes its sign.

15. The method of one of claims 12 to 14,
characterized in that
the maximum angular speed of the crank (15) when retracting the at least one reciprocating conveying means (35) is bigger than the maximum angular speed of the crank (15) when pushing said at least one reciprocating conveying means (35) forward.

Fig. 1

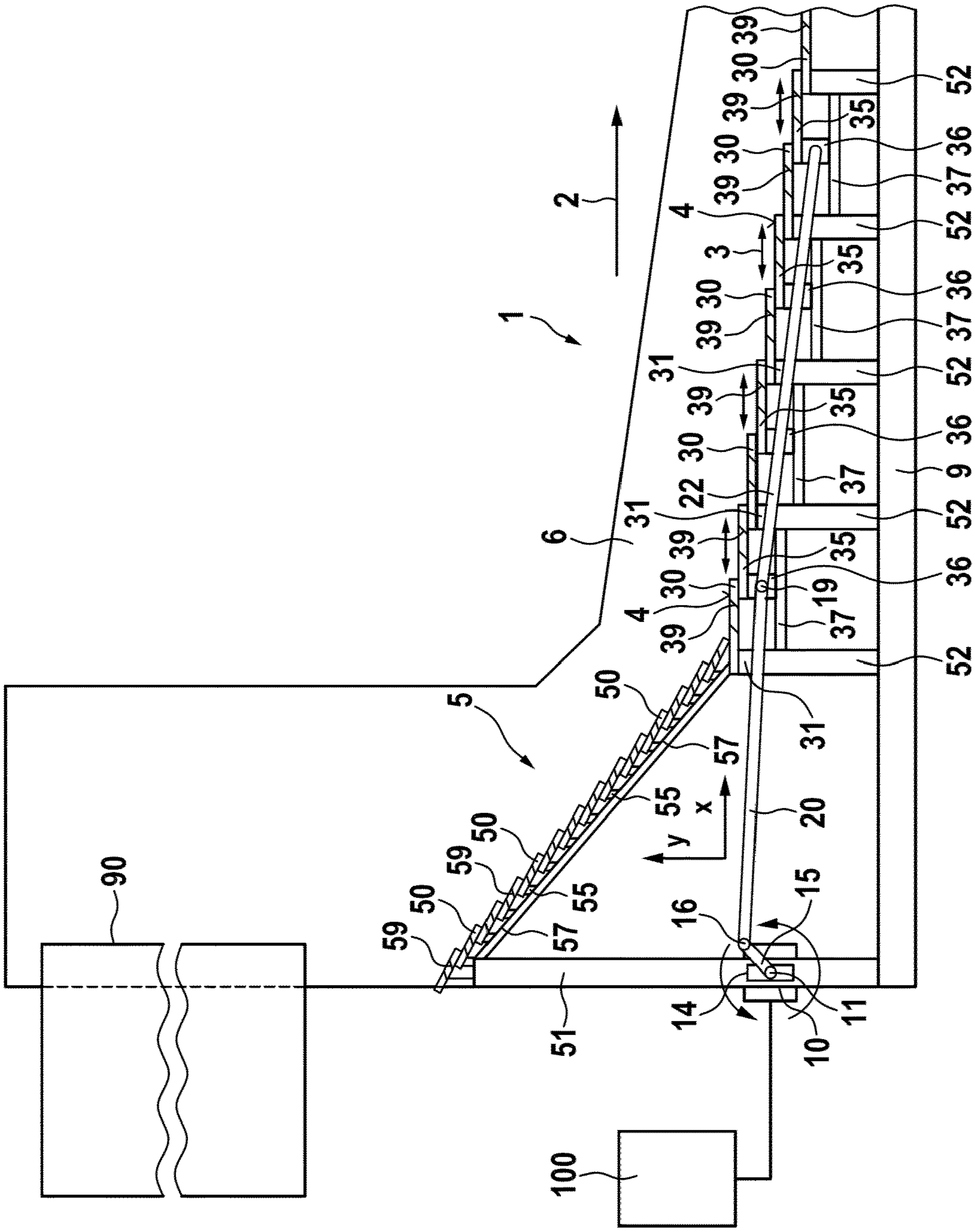

1
2
3
4
5
6
9
10
11
14
15
16
19
20
22
30
31
35
36
37
39
50
51
52
55
57
59
90
100
x
y

Fig. 2

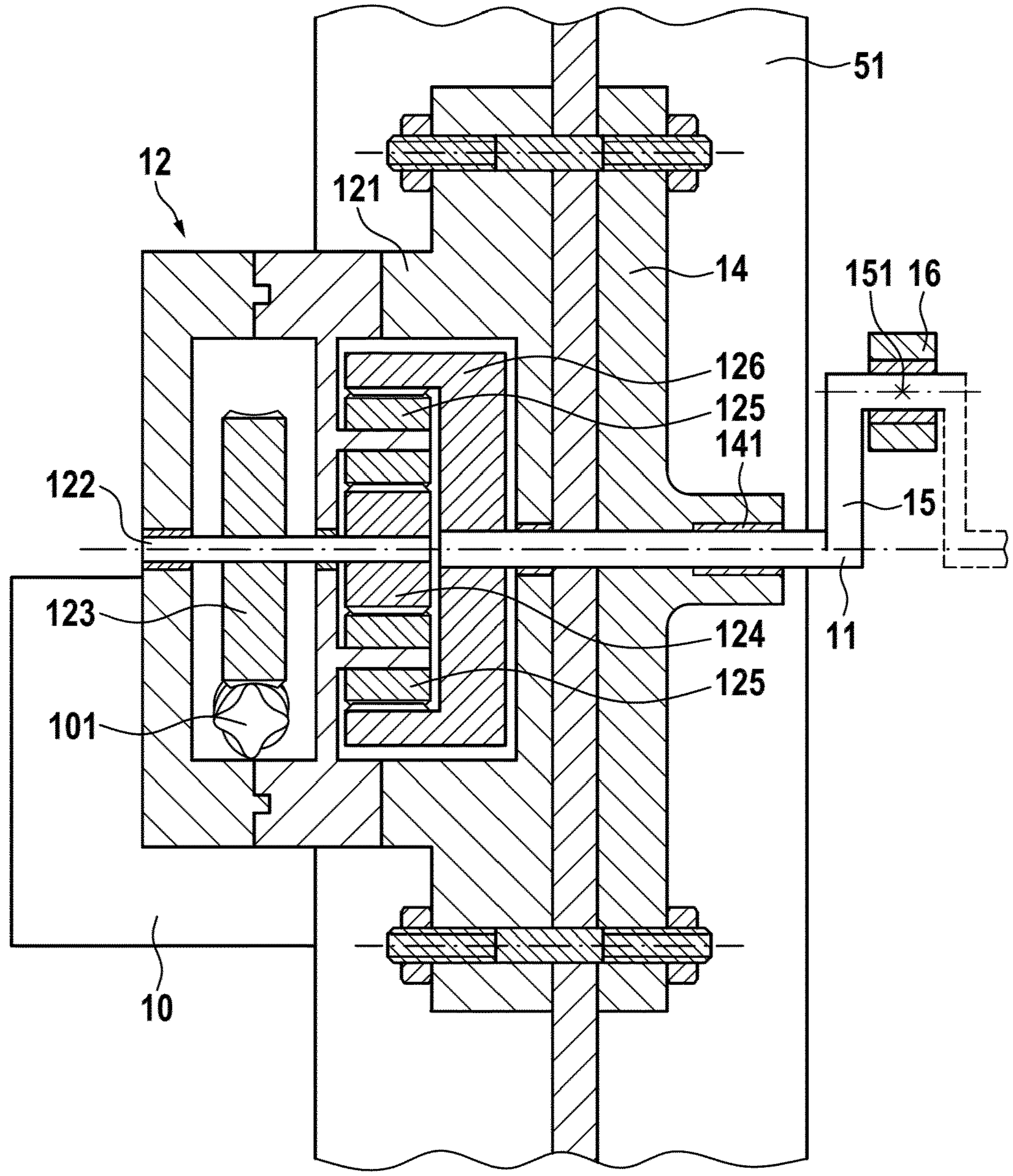


Fig. 3

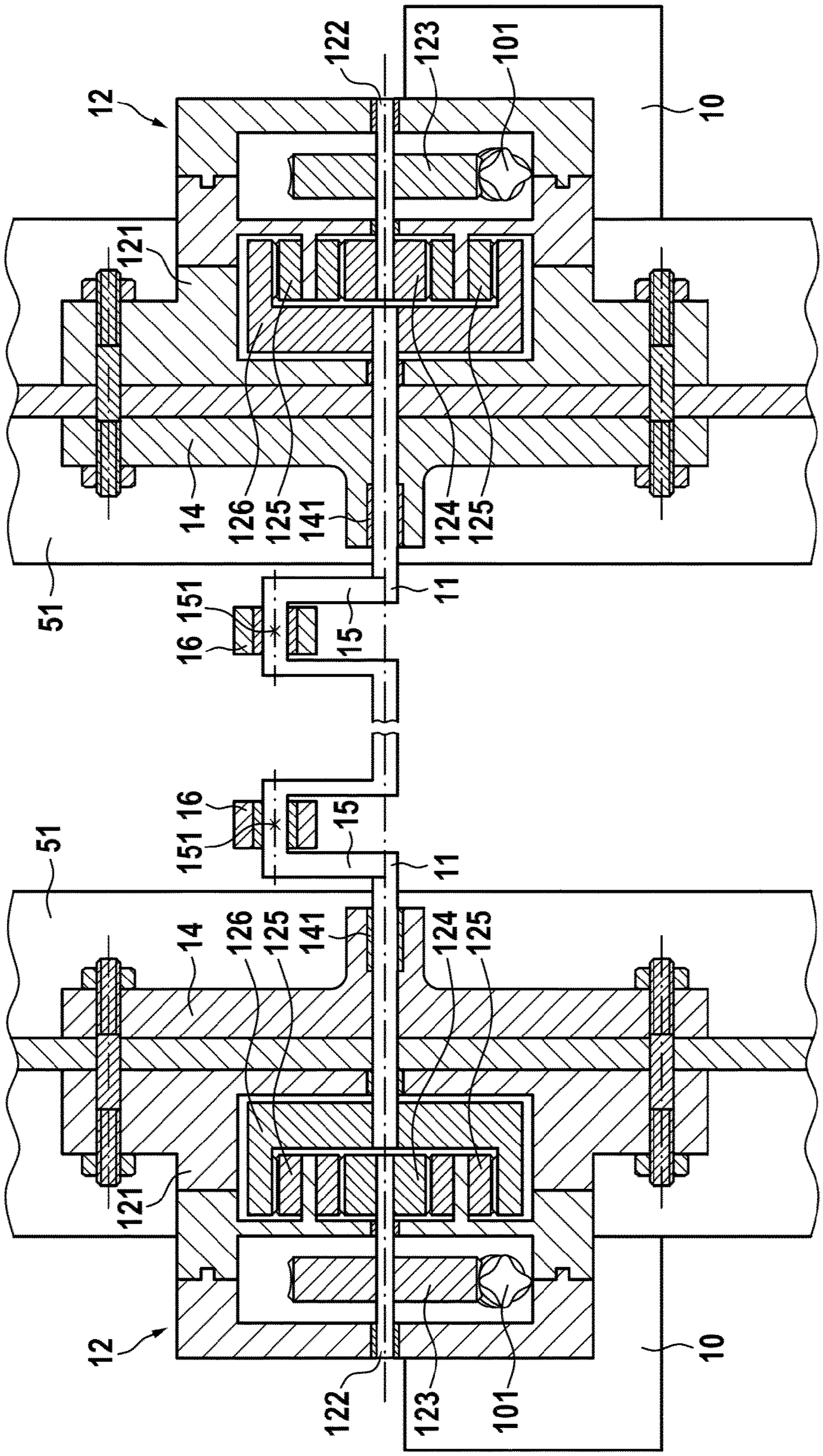


Fig. 4

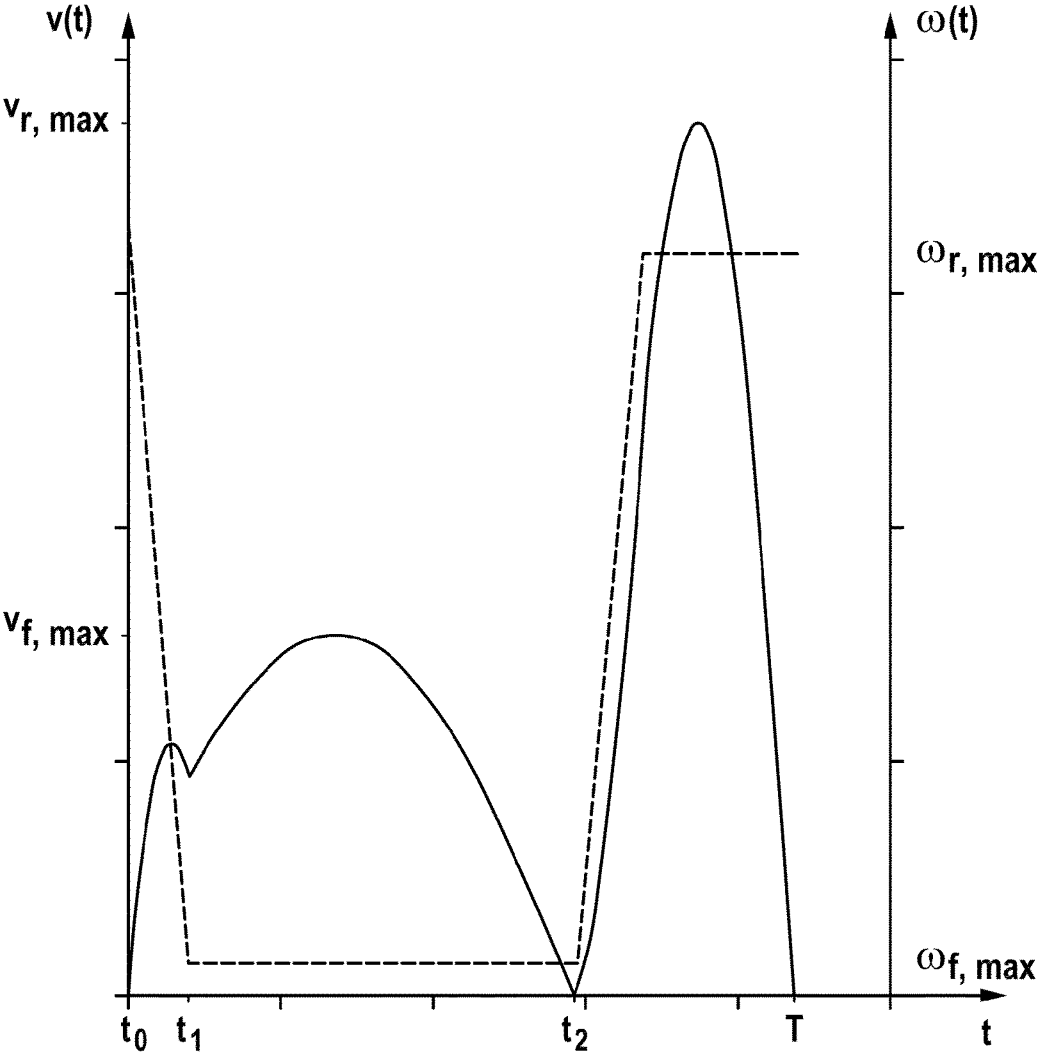
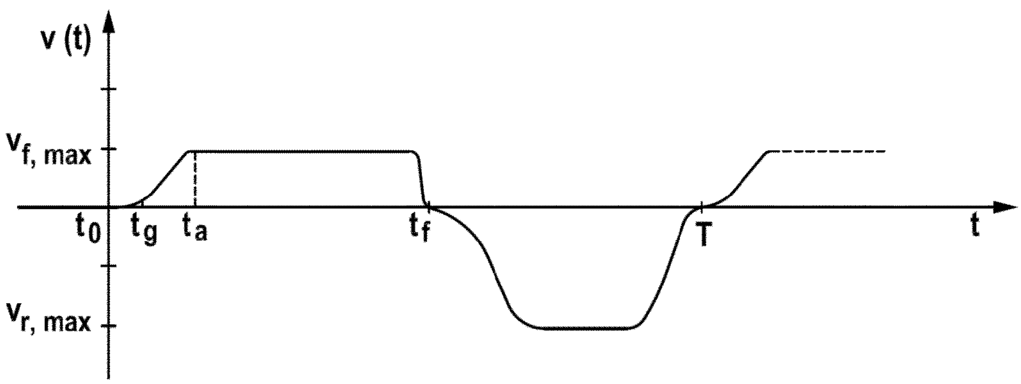

v(t)
ω(t)
v r, max
ω r, max
v f, max
ω f, max
t0
t1
t2
T
t

Fig. 5


v (t)
v f, max
v r, max
t0
tg
ta
tf
T
t

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 15 18 0131

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 260 432 A2 (KRUPP POLYSIUS AG [DE]) 23 March 1988 (1988-03-23) * figures 1-3 * * column 1, lines 4-10 * * column 1, line 36 - column 2, line 45 *	1-15	INV. F27B7/38 B65G23/00 F27B7/42 F27D15/02 F27D19/00 F27D21/00
X	DE 878 625 C (VOGEL-JORGENSEN MIKAEL DIPL-IN) 5 June 1953 (1953-06-05) * figures 2,6 * * claim 1 *	1-15	
X	FR 1 316 779 A (CALIFORNIA PORTLAND CEMENT CO) 1 February 1963 (1963-02-01) * figure 1 *	1-15	
X	CN 202 485 465 U (TAIAN ZHONGYI POWDER HEAT ENGINEERING INST) 10 October 2012 (2012-10-10) * figure 1 *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

F27D
F27B
B65G

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
The Hague	19 January 2016	Peis, Stefano

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 18 0131

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

19-01-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0260432 A2	23-03-1988	DE 3631974 A1	31-03-1988
		EP 0260432 A2	23-03-1988
		US 4778381 A	18-10-1988
DE 878625 C	05-06-1953	NONE	
FR 1316779 A	01-02-1963	NONE	
CN 202485465 U	10-10-2012	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- EP 2843342 A **[0003]**
- DE 202006012333 U1 **[0003]**
- DE 102006037765 A1 **[0003]**
- US 8397654 B **[0003]**
- EP 786637 A1 **[0003]**
- EP 0718578 A2 **[0003]**
- DE 2346795 **[0003]**
- DE 1985673 **[0003]**
- DE 10118440 **[0037]**
- DE 1841381 **[0037]**