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

(11) **EP 2 700 604 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.02.2014 Bulletin 2014/09

(51) Int Cl.:
B66C 13/06 *(2006.01)*

(21) Application number: **12181009.7**

(22) Date of filing: **20.08.2012**

(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

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(54) **Anti-sway control method and arrangement**

(57) The invention is based on the idea of detecting a pendulous swaying motion of a load (8) and at least two positions (12, 13; 13, 14) of the pendulous motion. The pendulous motion is dampened by reeling in a rope (6) hanging the load when the load is near an extreme position (12, 14) and reeling off the rope when the load is near the equilibrium position (13). The reeling in and reeling off periods can be calculated from the at least two detected positions.

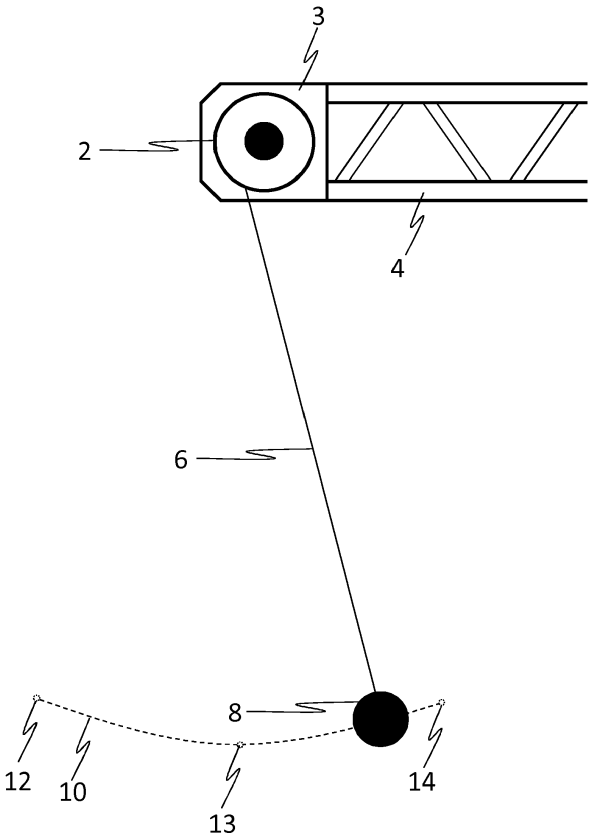

Fig.1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method of controlling a crane and a crane arrangement.

BACKGROUND OF THE INVENTION

[0002] Moving of a crane trolley or a crane boom which holds a load hanging by a rope causes swaying motion to the load. Usually the swaying of the load must be dampened before the load can be lowered to ground. A problem with the swaying load is that without any counter measures it takes a long time before the load is still after it has been moved and this waiting time decreases productivity of the crane significantly.

[0003] The problem has been addressed in the prior art. The prior art solutions try to solve the problem by measuring and controlling accelerations of a crane boom or a crane trolley in order to dampen the swaying motion of a load. One example of the prior art is described in European patent EP0717004. The patent discloses a method for damping a load swing of a crane during a traversing motion of a load-carrying trolley. The method comprises determining substantially continuously the acceleration of the trolley/bridge and an instantaneous swing time constant, swing velocity and deviation from equilibrium of a pendulum formed by the load. When the velocity reference changes, the acceleration providing the desired change in velocity is determined and that acceleration is switched on immediately. The acceleration compensating for the swing prevailing at the moment of change of the velocity is determined and that acceleration is switched on either immediately or, if the compensating acceleration exceeds the maximum acceleration permissible to the traversing drive when switched on immediately, when the pendulum formed by the load has reached its extreme position.

[0004] The disclosed method requires complex measurements and calculations of velocities and accelerations of different elements of the system. Another shortcoming is that the method functions only with a small amplitude pendulous motion. Elimination of large amplitude pendulous motion requires higher acceleration rates from the traversing drive than it is capable of providing.

BRIEF DESCRIPTION OF THE INVENTION

[0005] An object of the present invention to provide a method and an apparatus for implementing the method so as to alleviate the above disadvantages. The objects of the invention are achieved by a method and an arrangement which are characterized by what is stated in the independent claims. The preferred embodiments of the invention are disclosed in the dependent claims.

[0006] The invention is based on the idea of detecting a pendulous swaying motion of a load and at least two positions of the pendulous motion, for example both extreme positions or one extreme position and an equilibrium position. The pendulous motion is dampened by reeling in a rope hanging the load when the load is near an extreme position and reeling off the rope when the load is near the equilibrium position. The reeling in and reeling off periods can be calculated from the at least two detected positions.

[0007] An advantage of the method and arrangement of the invention is that the arrangement is very simple and usually it requires very little or no additional hardware to a crane arrangement. The detection steps can be realized by measuring an electrical response caused by the swaying load to the reel's drive. Another advantage is that the method can be applied to virtually any amplitude of pendulous motion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached [accompanying] drawings, in which

[0009] Figure 1 illustrates an example of a crane arrangement with a load in pendulous motion;

[0010] Figure 2 illustrates an embodiment of a crane arrangement with a load controlled along a first path;

[0011] Figure 3 illustrates an embodiment of a crane arrangement with a load controlled along a second path;

DETAILED DESCRIPTION OF THE INVENTION

[0012] Figure 1 illustrates an example of a crane arrangement. The invention may not be restricted to any specific type of lifting device or crane. The invention may be used in many different arrangements which comprise some kind of lifting device. A crane of Figure 1 is used as an exemplary embodiment due to its simple construction. In the embodiment of Figure 1 the crane arrangement comprises a crane boom 4, a reel arrangement 3 and a rope 6. The crane boom 4 may comprise a trolley and a trolley drive for moving the trolley along the crane boom wherein the reel arrangement may be fixed to the trolley or it can be a part of the trolley. The rope 6 may be winded around a reel 2 of the reel arrangement 3 and a load 8 is suspended by the rope 6. The rope may be for example a steel cable or some other string that is flexible enough so that it can be winded on the reel 2 and strong enough to lift and hold the loads 8 that are to be lifted with the crane arrangement. In addition to the reel 2 the reel arrangement 3 comprises a reel drive for rotating the reel and a controller for controlling the reel drive. Preferably the controller is programmable and has means for measuring electrical parameters of the reel drive. The controller may also have communications means e.g. for receiving instructions and transmitting measurement results. The reel arrangement may comprise multiple ropes on one or more reels which may be

controlled with one or more controllers.

[0013] When the crane boom or the trolley and the reel with it is moved to a certain position the load will move and start swinging in pendulous motion 10 below the position where the reel was moved. Amplitude of the pendulous motion depends on the movement of the reel. High acceleration results in high amplitude to the pendulous motion and low acceleration results in low amplitude of the pendulous motion. The pendulous motion 10 has three special positions: an equilibrium position 13 and two extreme positions 12, 14. In the equilibrium position 13 the load 8 has minimum potential energy and maximum kinetic energy. In the extreme positions 12, 14 the load 8 has maximum potential energy and no kinetic energy.

[0014] The pendulous motion of the load 8 is dampened if the load 8 is lifted up at the extreme positions 12, 14 and lowered down at the equilibrium point 13. However, moving a mass almost instantaneously requires very high peak power and very strong ropes or cables which hold the mass. Therefore, in practice, the load 8 has to be lifted up near the extreme points 12, 14 by reeling in the rope 6 that holds the load 8. Similarly the load 8 has to be lowered near the equilibrium point 13.

[0015] Figure 2 illustrates an example of a practical path 20 for dampening pendulous motion of a load 8. Only a moderate peak power is required to make the load 8 follow the path 20 because the load is lifted and lowered with a relatively low speed. The lifting of the load 8 may begin when the load approaching the extreme point 14 has passed the middle point between the equilibrium position 13 and the extreme position 14. The load may be lifted continuously until the load reaches again the middle point between the equilibrium position 13 and the extreme position 14, now approaching the equilibrium position 13. At the same point, the load may be lowered down and the lowering may continue when the load 8 passes the equilibrium point 13 until the load reaches the middle point between the equilibrium point 13 and the extreme point 12. At this point, the load may be lifted again and the lifting may continue when the load reaches the extreme point and starts to approach the equilibrium point 13. Again, the lifting may continue until the load reaches again the middle point between the extreme point 12 and the equilibrium point 13 wherein lowering of the load may begin again.

[0016] Figure 3 illustrates an example of a practical path 30 for dampening pendulous motion of a load 8. The path 30 of Figure 3 requires higher peak power than following the path 20 of Figure 2 because the movements of the load 8 are realized in much shorter period of time. However, following the path 30 of Figure 3 dampens the pendulous motion 10 of the load 8 faster than following the path 20 of Figure 2. In addition, faster movements will cause more stress to crane structures, so the path 30 of Figure 3 is usable with relatively light loads compared to the lifting capacity of the crane structure.

[0017] The suspended load 8 that is in pendulous motion 10 causes an alternating force to the rope 6 and the alternating force causes an alternating torque to the reel 2 of the reel arrangement 3. The torque may be detected and measured electrically with the reel drive and/or the controller of the reel arrangement. The alternating torque has to be compensated with certain amount of power at the reel arrangement in order to prevent the reel from rotating. The amount of power needed to compensate the alternating torque may be measured to detect changes in the torque. The required measurements may be realized with modern electrical drives and controllers without any additional components in the electrical drive. Functions, properties and/or operations of the reel arrangement may already be monitored in existing reel arrangements so the changes caused by the load in the pendulous motion have to be identified and extracted from the monitored data.

[0018] The suspended load in the pendulous motion causes maximum torque to the reel at the equilibrium point and minimum torque at the extreme points. In optimal conditions, half a cycle of the pendulous motion, i.e. from one extreme point 12 to the other extreme point 14, is enough to determine values for quantities necessary for dampening the load's motion. In some cases even a quarter of a cycle, i.e. from one extreme point 12 to the equilibrium point 13, may be enough for measuring the needed initial values. Duration of a cycle may be calculated or estimated when at least two points of pendulous motion are detected. Similarly, next moments of time when the load is at extreme point or equilibrium point may be calculated or estimated when the at least two points of pendulous motion are detected and time stamped. The extreme points 12, 14 may be detected also when the pendulous motion is being dampened by alternately ascending and descending the load.

[0019] The dampening actions do not have to happen at an exact point of the pendulous motion to be effective. Therefore good estimates of next moments of time when the load is at a critical point will also result to faster dampening than without any actions. In an embodiment, certain dampening actions may be omitted during certain cycles to improve detection accuracy of the extreme points. For example, the pendulous motion of the load is only monitored and measured during the first cycle. On the second cycle the load is ascended near one of the extreme points 12. On the third cycle the load is descended near the equilibrium point 13. On the fourth cycle the load is again ascended near one of the extreme points 12, then descended again near the equilibrium point 13, and so on.

[0020] In some cases, it may be useful to amplify the amplitude of the pendulous motion of the load. The amplitude may be amplified by reversing the movement directions of the dampening actions, i.e. ascending the load near the equilibrium point 13 and descending the load near the extreme points 12, 14.

[0021] In typical reel arrangements it is possible to descend a load until it reaches ground level or all the rope

is reeled out. Similarly, the load can be ascended by reeling in the rope until the load blocks movement of the reel. In an embodiment where the only function of a crane arrangement is to dampen or amplify the amplitude of the pendulous motion of the load the rotating reel and reel drive may be substituted with a linear drive arrangement. The linear drive arrangement may have a limited capacity for ascending and descending the load, for example 20 centimeters, 50 centimeters, 1 meter or 2 meters from a centre position of the linear drive. The limited capacity means that in some cases the load can not be descended to ground level or ascended all the way up to touch the linear drive arrangement. In an embodiment, a crane arrangement comprises a reel and a reel drive for ascending and descending a load to different heights and a linear drive arrangement for ascending and descending the load only for purpose of dampening and amplifying the pendulous motion of the load. Similar methods may be used for dampening the pendulous motion of a load with the linear drive arrangement as described above in connection with the reel arrangements.

[0022] It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A method of controlling a crane for dampening a swaying of a load (8) suspended by a rope (6), **characterized in that** the method comprises steps of:

   detecting the swaying of the suspended load (8),
   detecting at least two positions of a pendulous motion (10) of the swaying suspended load (8),
   reeling in the rope suspending the load near extreme points (12, 14) of the pendulous motion (10) of the load (8), and
   reeling off the rope suspending the load near an equilibrium point (13) of the pendulous motion (10) of the load (8).

2. A method according to claim 1, **characterized in that** the detection of the swaying of the suspended load (8) is performed by measuring torque caused by the suspended load (8) to a drive of the crane.

3. A method according to claim 1 or 2, **characterized in that** the detection of the at least two positions of a pendulous motion of the swaying load (8) is performed by measuring torque caused by the swaying load (8) to a drive of the crane.

4. A method according to any one of claims 1 to 3, **characterized in that** the steps of reeling in the rope (6) and reeling off the rope (6) are performed in such a manner that a path (20, 30) of the suspended load (8) has a shape of a figure of eight in a plane defined by the pendulous motion of the suspended load (8).

5. A method according to any one of claims 1 to 4, **characterized in that** the method further comprises a step of calculating an instance of time in the future when the load is at an extreme point (12, 14) of the pendulous motion based on the at least two detected positions of the swaying load (8).

6. A method according to any one of claims 1 to 5, **characterized in that** the method further comprises a step of calculating an instance of time when the load will be at equilibrium point of the pendulous motion based on the at least two detected positions of the swaying load.

7. A method according to any one of claims 1 to 6, **characterized in that** the method further comprises a step of calculating a period of the pendulous motion based on the at least two detected positions of the swaying load (8).

8. A method according to any one of claims 1 to 7, **characterized in that** the method further comprises a step of calculating the time between the detected at least two positions of a pendulous motion of the swaying load (8).

9. A method according to any one of claims 1 to 8, **characterized in that** the step of reeling in the rope (6) takes place only when the load (8) is closer to an extreme point (12, 14) than the equilibrium point (13) of the pendulous motion of the swaying load (8) and the step of reeling off the rope (6) may take place only when the load (8) is closer to the equilibrium point (13) than an extreme point (12, 14) of the pendulous motion of the swaying load (8).

10. A method according to claim 2 or 3, **characterized in that** the torque is measured by measuring electrical response caused by the torque in a reel drive arrangement.

11. A method according to any one of claims 1 to 10, **characterized in that** at least one of the at least two positions to be detected is one of the following: an equilibrium point (13) of the pendulous motion and an extreme point (12, 14) of the pendulous motion.

12. A crane arrangement comprising a movable crane boom (2), a reel (4) adapted to receive a rope (6) for ascending and descending a load (8), a drive for rotating said reel in order to reel in and reel off the rope (6), and a controller for controlling said drive, **characterized in that** said controller has means for de-

tecting at least two positions of a pendulous motion of a load (8) and means for reeling in the rope near extreme points of the pendulous motion and reeling off the rope near an equilibrium point.

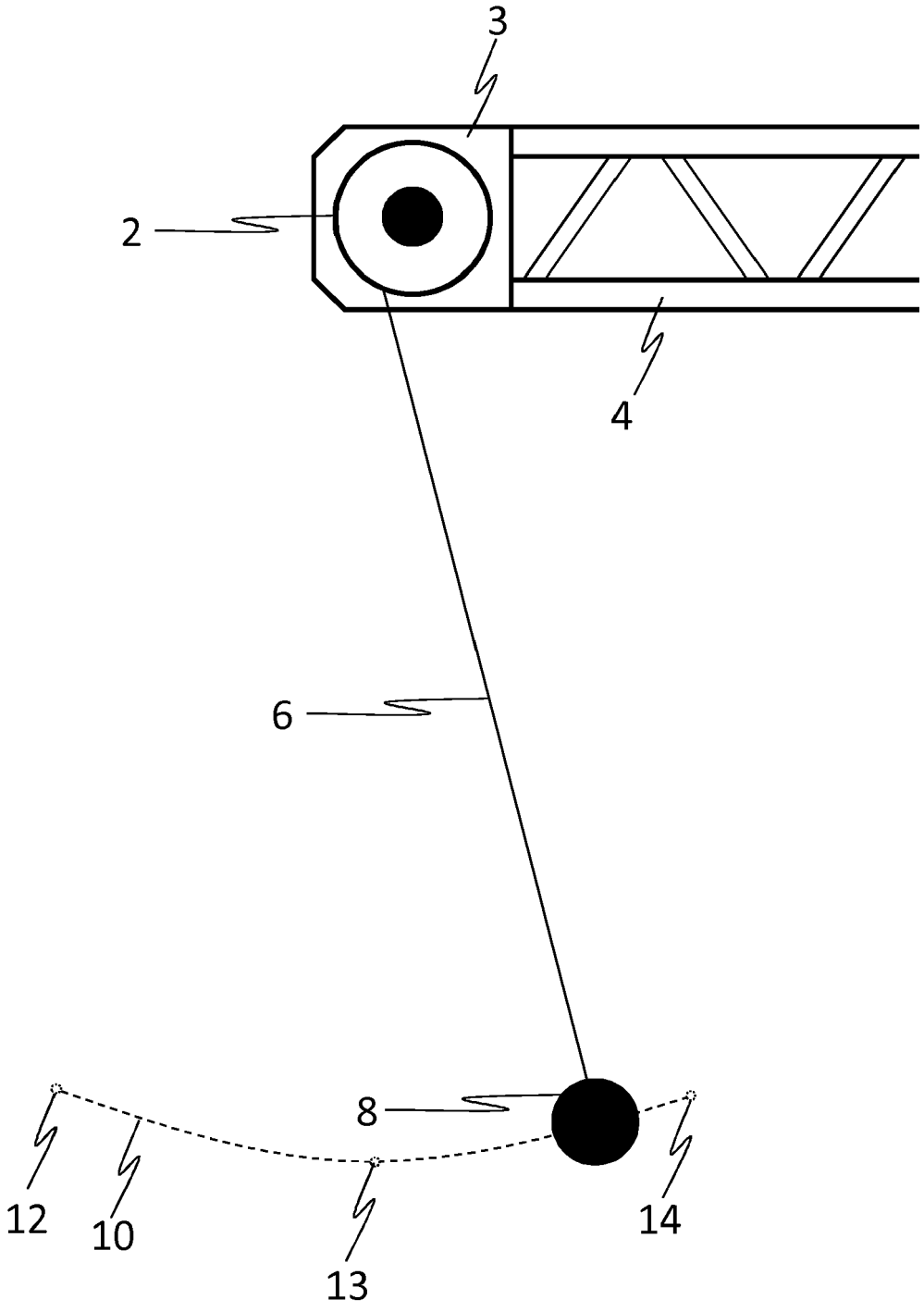

Fig.1

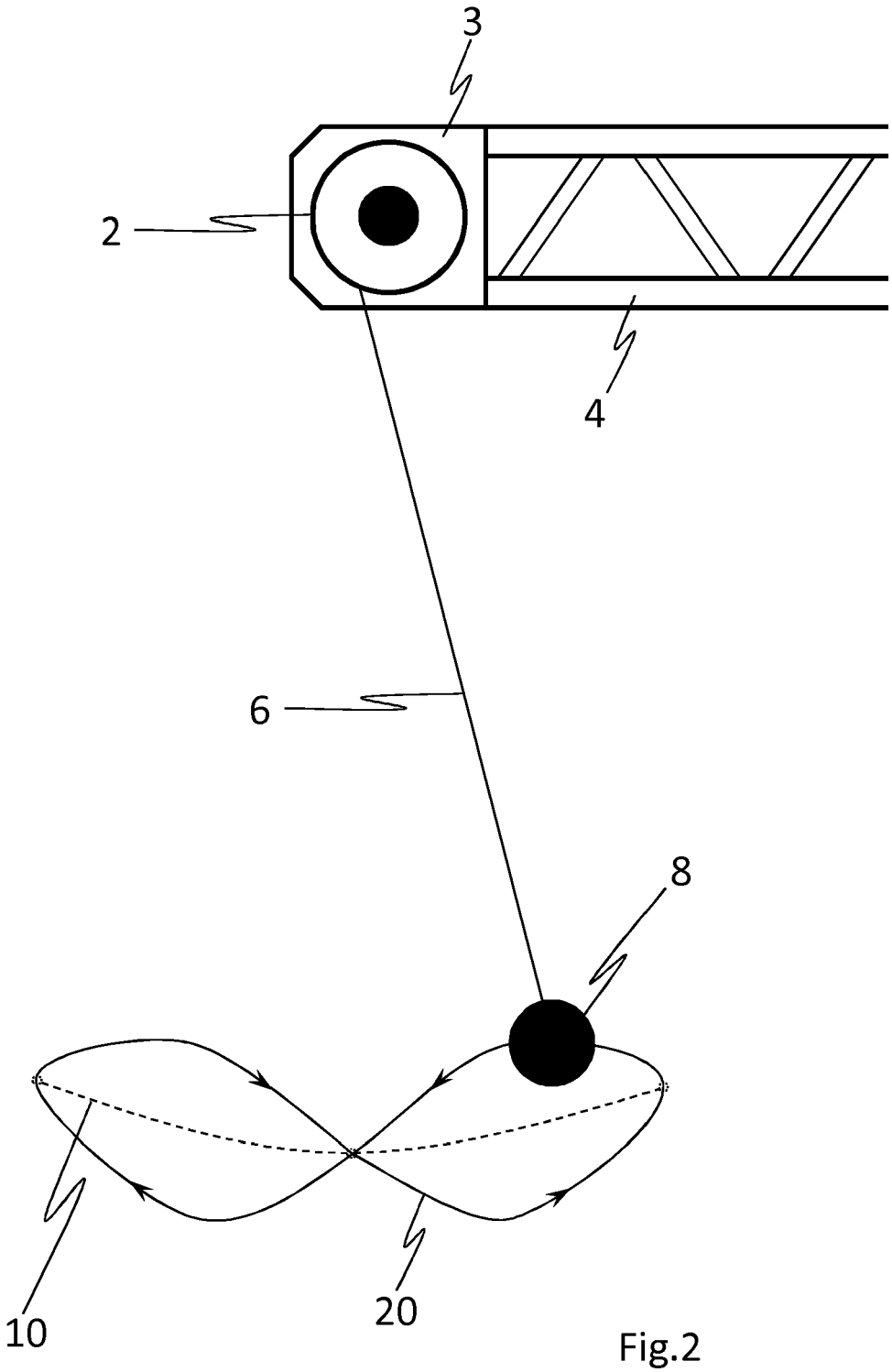

Fig.2

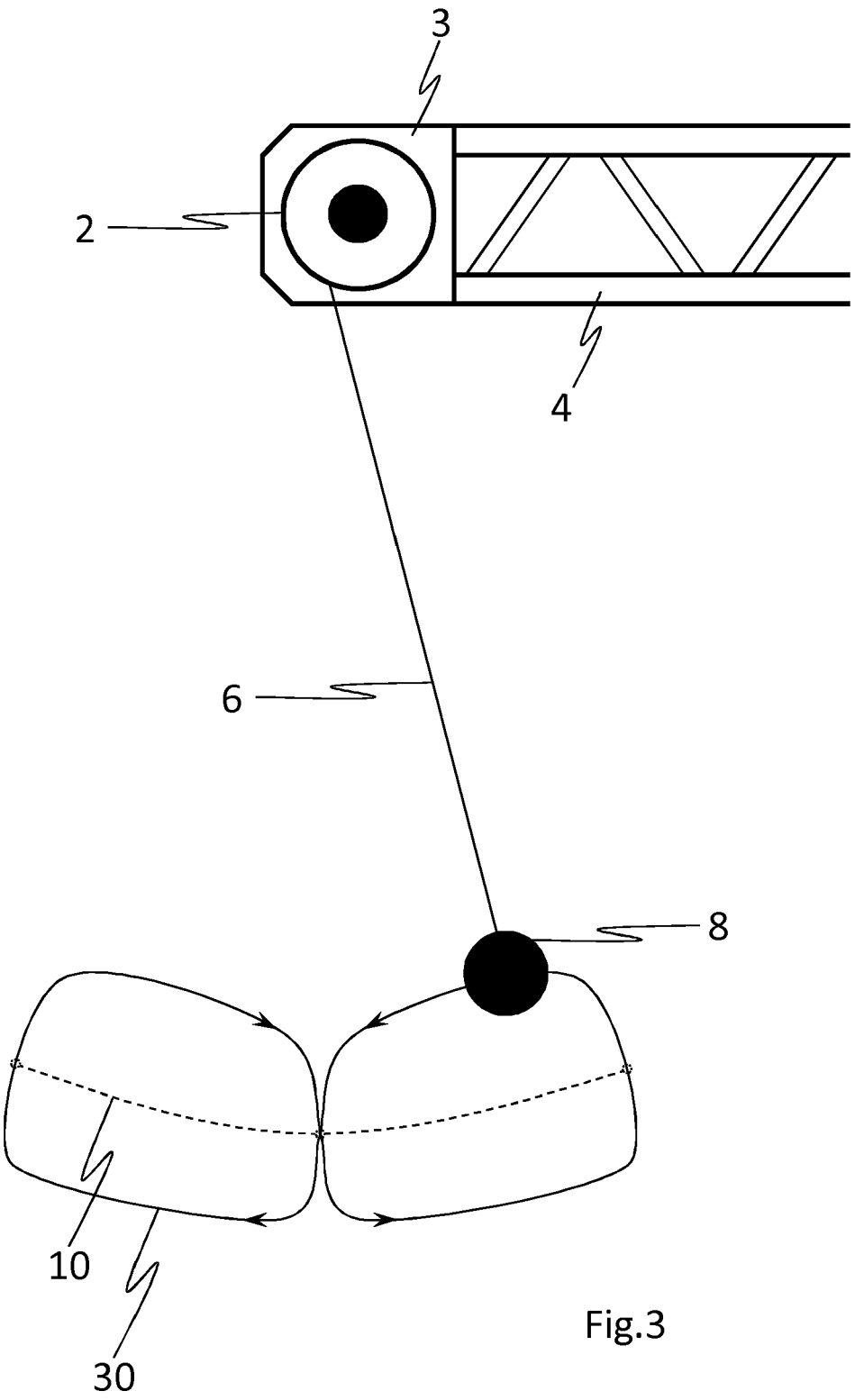

Fig.3

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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 1009

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 Y	US 2005/224438 A1 (MAURER PETER [DE] ET AL) 13 October 2005 (2005-10-13) * paragraphs [0002], [0019], [0039], [0040] * * figures 1,2 * -----	1,4-9, 11,12 2,3,10	INV. B66C13/06
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TECHNICAL FIELDS SEARCHED (IPC)

B66C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 October 2012	Fiorani, Giuseppe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 18 1009

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

REFERENCES CITED IN THE DESCRIPTION

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