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METHOD AND DEVICE FOR DAMPING TOWER OSCILLATIONS OF A WIND TURBINE

Description

The invention relates to a method and to a device for damping tower oscillations in a wind turbine, in particular during the erection phase.

In strong winds, wind turbines are exposed to major time-variable loads. Wind turbines are designed according to international regulations so that they can withstand very high wind speeds. For the design of the towers of wind turbines, oscillations have to be additionally taken into account which are triggered by air vortices alternating laterally along the tower height. The oscillations occur transversely to the inflow direction of the wind turbine within a critical wind speed range. Basically, these vortex-induced vibrations are relevant with respect to damaging of components by fatigue. In addition to this, the load capacity of the tower can be at risk. Because of the influence of the rotor, the tower is not endangered in every inflow direction by vortex-induced vibrations with large amplitudes.

Reducing oscillations of the tower of a wind turbine is important in particular when the wind turbine is still in an installation phase and the oscillations cannot yet be countered with active control measures such as for example a yaw and/or rotor blade adjustment. Various devices and apparatuses for damping tower oscillations are known.

From DE 103 09 825 A1 for example a wind turbine having a tower provided with guys is known for damping oscillations of the tower, where controllable hydraulic damping apparatuses are arranged on the tower side in the force flow of the guys.

US 9 150 380 B2 shows a wind turbine with a tower equipped with guys, wherein, for damping oscillations of the tower, spring-based mechanical damping apparatuses are provided on the ground side.

WO 2015/110580 A1 discloses a tower for a wind turbine having six guy elements that are inclined relative to a longitudinal axis of the tower, through which the tower is guyed in sections. The guy elements are each fastened to a load introduction point of the tower that is radially spaced apart from the tower wall of the tower and anchored in the ground radially outside the tower, wherein each guy element extends tangentially to the tower wall from the load introduction point to the ground.

These systems function satisfactorily during the operation. However, the permanent use of such guys has substantial disadvantages in wind turbines since wind turbines are exposed to dynamic loads. The forces introduced into the wind turbine at the force introduction points caused by the guys can result in material fatigue problems. Additionally disadvantageous is the increased space requirement permanently claimed by the guying device compared with a tower without guys.

As a further prior art, US 2009/0142178 A1 is known. Here, a wind turbine is disclosed among other things having a tubular steel tower and a control for determining oscillation control values of the wind turbine. The wind turbine is able to change the load for optimizing the tower natural frequency as a reaction to the detected values by the control. The invention also relates to a control system and to a method for changing the natural frequency of a tower of a wind turbine. For this purpose, load changing means in the form of connecting means, which are designed as two wires, rods or the like, are braced in the tower in the longitudinal direction. By changing the tension of the connecting means it is possible to change the stiffness of the tower, as a result of which the critical natural frequency or the critical natural frequencies of the tower can also be changed. The aforementioned optimization of the stiffness of the tower can also be utilized during the erection of the wind turbine.

In JP S60126473, a vibration damping apparatus for a tower-like structure is shown, which is arranged outside the tower-like structure in the form of a rope from the tip to the foundation of the tower-like structure and configured to change the direction of the force of a weight acting on the rope. A hydraulic damper is connected to the rope.

Summary of the invention

It is an object of the invention to provide a method for damping oscillations of a tower of a wind turbine, in particular during the erection of the tower and the wind turbine, wherein the tower comprises a plurality of tower sections of steel or concrete and wherein an adaptation of a damping device to the wind turbine is to take place easily and in particular without a foundation that is permanently introduced in the ground. Corresponding to this, it is an object of the invention to provide a corresponding damping device for a tower of a wind turbine which is modularly constructed and temporarily and flexibly adaptable and useable for various tower heights and tower diameters.

The object is achieved through a method for damping oscillations of a tower of a wind turbine during the erection of the tower and the wind turbine, which comprises a plurality of tower sections of steel or concrete, each of which have a lower and an upper connection element, wherein on at least one tower section at least one force-absorbing element, preferably two, particularly preferably four force-absorbing elements are arranged adjacent to the upper connection element, with the steps:

a) erecting a tower with a plurality of tower sections,
b) fastening a first end of a first steel cable, namely of a spiral cable, to a first force-absorbing element of a predetermined tower section,
c) connecting the second end of the first steel cable to an end of a second steel cable, namely a round strand cable,
d) guiding the second steel cable through a deflecting unit of a first damping apparatus having at least one deflecting means, wherein the damping apparatus is positioned on a terrain surface outside the tower and spaced apart from the tower, and
e) connecting the other end of the second steel cable to a ballast mass of the first damping apparatus.

For damping transverse oscillations, the force-absorbing element is advantageously oriented and/or mounted to the tower section substantially transversely to a main wind direction prior to the fastening of the first end of the steel cable. The main wind direction is a direction from which the wind blows particularly often and/or for particularly long periods. Preferentially, the force element is arranged adjacent to the upper connection element, wherein the connection element in the case of tubular steel tower sections is preferably formed as a ring flange.

In a preferred further development of the method, a second force-absorbing element is arranged or mounted to the tower section in such a manner that the same is offset by approximately 90° on the circumference of the tower section relative to the position of the first force-absorbing element. This is followed by the additional steps:

k) fastening a first end of a third steel cable, in particular of a spiral cable to the second force-absorbing element of the or a further tower section, wherein the further tower section is arranged above the previously installed tower section,

l) connecting the second end of the third steel cable to an end of a fourth steel cable, preferentially a round strand cable,

m) guiding the fourth steel cable through a deflecting unit of a second damping apparatus having at least one deflecting means,

n) connecting the other end of the fourth steel cable to a ballast mass of the second damping apparatus.

By way of this, a change of the wind direction is taken into account on the one hand. On the other hand, by way of a second damping device together with guy ropes or steel cables on another, in particular upper tower section it is ensured that during the "growing" of the tower during the erection, a damping device is always effective.

Preferably, the method is carried out with the additional steps:

positioning the first and/or the second damping apparatus radially spaced apart or distant from the tower so far that the angle of the spiral cable to a horizontal plane on the damping apparatus is 30° to 80° and/or the distance to the tower approximately 25 to 240 metres. Here, the degree of the erection, namely partly erected tower, complete tower without or with installed nacelle and if applicable with mounted rotor blades is taken into account. Furthermore, the type of terrain is taken into account. Not least, the mass and the sag of the respective guy rope or steel cable is taken into account.

Particularly preferably, the method is carried out with the additional steps: adjusting the first and/or second damping apparatus to a predetermined damping value by changing the position of the at least one deflecting means in such a manner that an overall wrap angle β (beta) and thus the friction resistance is reduced or increased. In the case that the damping apparatus comprises two deflecting means, the adjusting of the first and/or second damping apparatus to a predetermined damping value is effected by changing the position of a first deflecting means and/or of a second deflecting means in such a manner that the distance between the first deflecting means and the second deflecting means and thus the overall wrap angle β (beta) and thus the friction resistance is reduced or increased, wherein the overall wrap angle β (beta) is formed of the individual wrap angles β_1 (beta1) of the first deflecting means and β_2 (beta2) of the second deflecting means. The wrap angle indicates the contact region of the cable with the deflecting means.

In the case that the first and/or second damping apparatus is of a different design with a pivot lever and an adjustable friction unit that is operatively connected to the same, the adjusting of the damping apparatus to a predetermined damping value is effected by changing the angular position of the pivot lever.

At the start and/or during the carrying out of the method according to the invention, preferentially a determining of the wind direction and of the wind strength as well as the tower movements takes place with the help of suitable sensors in order to be able to specifically adjust and if applicable readjust the damping effect.

Following the commissioning of the wind turbine, the following further steps take place particularly preferably: disassembling the steel cable or the steel cables by means of a guide or auxiliary rope and removing the damping apparatus.

The object is also achieved through a damping device for a tower of a wind turbine having a plurality of tower sections of steel for carrying out the method, comprising a damping apparatus, which comprises a rack, for example a steel frame, a deflecting unit and a ballast mass, wherein the damping apparatus is positioned on a terrain surface outside the tower and spaced apart from the tower, and comprising a steel cable guided over the deflecting unit, which on the one hand is connected to the ballast mass and on the other hand to at least one force-absorbing element on at least one tower section, wherein the deflecting unit comprises at least one first deflecting means, wherein the first deflecting means is variable in its position for changing the damping. According to the invention, the steel cable has a first portion which is formed as spiral cable and fastened to the force-absorbing element of the tower section, and a second portion, which is formed as round strand cable, which is guided over the deflecting unit and connected to the ballast mass of the damping apparatus, wherein the spiral cable and the round strand cable are, in particular detachably, connected to one another by way of a clamping connector. The combination and connection of two steel cable types according to the invention has many advantages with respect to the present object:

- the spiral cable is particularly suitable as a stiff connecting cable between the tower and damping apparatus, whereas the round strand cable can be particularly favourably guided over deflections and/or pulleys,
- the spiral cable is separately adaptable in terms of the tower height in length, diameter and mass,
- the round strand cable is separately adaptable in terms of the tower height in length, diameter and flexibility,
- the round strand cable can be provided separately with respect to the number of the round strands regarding the cable friction,
- when damaged, the spiral cable or the round strand cable can each be replaced individually,

- the assembly time for the installation of a damping device can be substantially shortened, e.g. the spiral cable can already be fastened to the horizontal tower section and the round strand cable can already be connected to the damping apparatus.

In an advantageous configuration, the spiral cable has a fastening element at its end that is distant from the clamping connector, which is detachably connectable or connected to a load fastening means on the tower section, in particular by means of further connection elements, wherein the fastening element can preferably be designed as a thimble or clevis.

At its end that is distant from the clamping connector, the round strand cable has a fastening element which is connectable or connected to the ballast mass.

Preferably, the damping device, besides the first, comprises a second deflecting means, wherein at least one deflecting means is movably mounted in at least one plane, preferably in two planes, as a result of which the overall wrap angle β (beta) for the steel cable is adjustable in particular in the range from 10° to 240°.

In an advantageous embodiment, the round strand cable is consecutively guidable or guided over the first and the second deflecting means, wherein the deflecting means have at least partly a convex surface of a material which, in conjunction with a round strand steel cable, produces in the dry state a sliding friction coefficient greater than 0.3, preferentially greater than 0.4. A hard wood and/or durable wood such as beech, oak or larch wood has been proved by tests to be a suitable material.

In an advantageous configuration, the first and/or the second deflecting means can each be designed as rigid deflection bars each with at least one rounded longitudinal edge or with a convex surface extending parallel to the longitudinal axis or as rotatable deflecting pulley that can be braked, which is movably mounted preferably transversely to the axis or shaft.

In an alternative preferred configuration of the damping apparatus with a pivot lever, which is operatively connected to a friction unit, the pivot lever is pivotably mounted on the friction unit and the friction unit comprises at least one stationary friction element and at least one movable friction element, wherein the movable friction element is operatively connected to the pivot lever.

Further preferably, the steel cable has a first portion formed as spiral cable and a second portion formed as round strand cable, wherein the spiral cable and/or the round strand cable are detachably fastened to the end of the pivot lever that is distant from the friction unit.

A tower of a wind turbine comprises a plurality of tower sections of steel or concrete, which each comprise a lower and an upper connection element, wherein on at least one tower section at least one force-absorbing element, preferably two and particularly preferably four force-absorbing elements are arranged adjacent to the upper connection element and wherein on the tower section a steel cable of a first damping device can be fastened to a first force-absorbing element at a predetermined height, wherein the steel cable has an end near the ground, which is connectable or connected to a ballast mass of a first damping apparatus on the ground side, which is positionable, spaced apart from the tower in the radial orientation from the centre axis of the same, in a vertical plane with the force-absorbing element, wherein the damping device is preferably designed as described above.

In a further development, a further steel cable of a second damping device is present, which can be fastened to a second force-absorbing element on the tower section, wherein the second force-absorbing element is offset by approximately 90° on the circumference of the tower section relative to the position of the first force-absorbing element. The steel cable of the second damping device has an end near the ground which is connectable or connected to a second ballast mass of a second damping apparatus on the ground side, wherein the damping apparatus is positionable spaced apart from the tower in the radial orientation from the centre axis of the same. The angle α (alpha) of the steel cable or of the steel cables with respect to the centre axis of the tower is preferentially in the range of 10° to 60°.

In a first advantageous configuration, the or each force-absorbing element, in particular load fastening means is held outside on the tower by means of an annular bracing element.

In a second advantageous configuration, the or each force-absorbing element, in particular load fastening means is formed as feed-through unit in the tower wall, wherein the feed-through unit in particular comprises a so-called swivel bracket, load ring, ring bracket or load bracket. For the sake of simplicity, the term load bracket is utilized in the following.

In a preferred further development, the tower wall, vertically above the or each first wall feed-through for the feed-through unit, comprises a second wall feed-through for feeding-through a guide rope, which is connectable or connected to the spiral cable by means of a cable knot via an oval ring.

In a preferred further development, a plurality of wind sensors is arranged on a or the tower section, wherein the wind sensors are preferably arranged annularly in a plane on the tower.

Particularly preferably, at least one acceleration or oscillation sensor is arranged on a or the tower section and/or in the nacelle, the signals supplied by these sensors can be fed directly or via an evaluation unit to a control unit of the damping apparatus.

By using the damping device according to the invention, an escalation of the oscillations of the wind turbine tower in the case of critical inflow is prevented, by way of which damage to the wind turbine can be sustainably avoided.

By using the damping device according to the invention, with a guy rope in the form of a steel cable that can be fastened at different heights, different natural modes can be countered, namely a first natural mode horizontally at the height of the tower head and a second natural mode with a so-called loop at a middle height of the tower.

The damping device according to the invention is characterized in particular in that it is employable quickly and with little expenditure in all life phases of a wind turbine, namely during the

- erection phase,
- operating phase,
- maintenance phase,
- shutting-down phase and
- disassembly phase.

In the following, two exemplary embodiments of the damping device according to the invention are described making reference to the attached drawings, in which

Fig. 1 shows a schematic view of a wind turbine having a damping device according to the invention,

Fig. 2 shows a schematic view of a tower section having a damping device in a first configuration according to the invention,

Fig. 3 shows a schematic plan view of a tower section having a damping device according to the invention,

Fig. 4 shows a schematic plan view of a tower section having two damping devices according to the invention,

Fig. 5 shows a further schematic view of a tower section having a damping device in the first configuration according to Fig. 2,

Fig. 6 shows a schematic view of a tower section having a damping device in a second configuration according to the invention,

Fig. 7 shows a schematic view of a tower wall feed-through unit of the invention and

Fig. 8 shows a schematic view of a tower wall feed-through having a guide rope.

Fig. 1 shows a wind turbine 1 having a tower 2, a nacelle 4 and a rotor 5. The rotor 5 comprises three rotor blades 8a, 8b, which are rotatably mounted on a rotor hub 6. Of the three rotor blades 8a, 8b, merely two rotor blades 8a and 8b are noticeable in the lateral view, wherein the rotor blade 8b is shown sectioned in the figure for better clarity. The tower 2 consists of a plurality of tower sections 3a, 3b, 3c, 3d, 3e arranged on top of one another, which are connected to one another by connection elements 9. In the steel tower shown in the exemplary embodiment, the connection elements 9 are formed as a ring flange 9a. As is noticeable in Fig. 1, a force-absorbing element 11 for fastening a steel cable 12 of a damping device 20 is provided in the upper portion of the fourth tower section 3d adjacent to the ring flange 9a on a tower fastening point (TAP). The lower end of the steel cable 12 is guided in a damping apparatus 21 of the damping device 20, wherein the damping apparatus 21 can be positioned on the terrain at different distances to the lowermost tower section 3a, for example by means of a forklift or wheel loader that is not shown, as is indicated by the double arrow.

Fig. 2 shows a portion of a tower 2 having a damping device 20 according to the invention. The tower portion exemplarily comprises three tower sections 3a, 3b, 3c. As is noticeable in Fig. 2, a force-absorbing element 11 and a feed-through unit 14 for fastening an upper portion of the steel cable 12 in the form of a spiral cable 12a is provided in the upper portion of the third tower section 3c, adjacent to the ring flange 9a, on a tower fastening point (TAP). The lower portion of the steel cable 12 in the form of a round strand cable 12b is guided in the damping apparatus 21. As is shown furthermore by Fig. 2, the second or lower end of the spiral cable 12a is connected to an upper end of the round strand cable 12b by way of a clamping connector 13, for example “Crosby First Grip 429”. The lower portion of the round strand cable 12b is guided through a deflecting unit 23, substantially consisting of two deflecting means 23a, 23b, of the damping apparatus 21 and connected to a ballast mass 24, which ensures the necessary preload. In the exemplary embodiment, the deflecting means 23a, 23b are mounted in a steel frame 22 with trapezoidal cross section.

Fig. 3 shows a schematic plan view of a tower section 3d of a tower 2 having a damping device 20 according to the invention. In the tower wall 10, four force-absorbing elements 11 each offset by 90º on the circumference are provided, wherein on the force-absorbing element 11, in the shown three o'clock position, the steel cable 12 is fastened and connected to the damping apparatus 21, where the steel cable 12 runs from the top into the deflecting unit 23. With respect to an imaginary compass rose, the damping apparatus 21 in Fig. 3 is oriented transversely to the (main) wind direction north indicated by the arrow W to the east.

Fig. 4 shows a schematic plan view of a tower section 3d of a tower 2 having two damping devices 20 according to the invention. In the tower wall 10, four force-absorbing elements 11 each offset by 90º on the circumference are again provided, wherein on the force-absorbing elements 11 in the shown three o'clock position and the 12 o'clock position a steel cable 12 each is fastened and connected to the associated damping apparatus 21. With respect to an imaginary compass rose, the first damping apparatus 21 in Fig. 4 is oriented towards east and the second damping apparatus 21 towards north, wherein here according to arrow W the (main) wind direction is northeast or the wind comes from northeast.

Fig. 5 shows a portion of a tower 2 having a damping device 20 according to the invention. Owing to the representation, the tower portion here merely comprises two tower sections 3a and 3b. As is noticeable in Fig. 5, a force-absorbing element 11 and a feed-through unit 14 are provided for fastening the upper portion of the steel cable 12 at an angle α (alpha) in the upper portion of the second tower section 3b adjacent to the ring flange 9a on a tower fastening point (TAP). It should be noted that the steel cable 12 or the spiral cable 12a and the round strand cable 12b always have a certain sag, which for the sake of simplicity is not shown in the figures. The lower portion of the steel cable 12 is guided in the damping apparatus

21 where it runs in the clockwise direction over the first (upper) deflecting means 23a and following this in the anti-clockwise direction over the second (lower) deflecting means 23b to the ballast mass 24, to which the steel cable 12 – or, more precisely, the round strand cable 12b (not explicitly shown in Fig. 5) – is connected. The distance r from the axis of the first (upper) deflecting means 23a to the centre axis 2a of the tower 2 determines, as one parameter of multiple parameters, the degree of damping or the damping effect of the damping device 20. A further parameter is the overall wrap angle β (beta), which is formed from the sum of the individual wrap angles β_1 (beta1) of the first deflecting means 23a and β_2 (beta2) of the second deflecting means 23b. As shown by the double arrows in Fig. 5 above the deflecting means 23a, 23b, these are mounted in the exemplary embodiment horizontally so as to be movable and fixable in the steel frame 22 – for the purpose of adjusting the wrap angles β_1 (beta1), β_2 (beta2) and thus the frictional force. The arrangements of the deflecting means 23a, 23b shown in Fig. 2 and in Fig. 5 are exemplary. The deflecting means 23a, 23b can also be arranged in different planes, for example in a common horizontal plane. The configurations of the deflecting means 23a, 23b for achieving a defined frictional force are manifold. The deflecting means 23a, 23b have at least partially a convex surface of a material which in conjunction with a round strand steel cable produces a sliding friction coefficient of greater than 0.3, preferentially greater than 0.4. A hardwood, such as beech or oak proved to be a suitable material through tests or larch as a durable wood. In a first configuration, the deflecting means 23a, 23b can be formed as rigid deflection bars or rigid deflection cylinders. In a second configuration, the deflecting means 23a, 23b can be formed as rotatable pulleys or cylinders in conjunction with an adjustable friction unit, in the simplest case an adjustable disc brake or disc clutch. In a further development of the deflecting means 23a, 23b which is not shown, these are controllable and/or regulatable in the position and/or the braking effect and thus the frictional effect, wherein an oscillation sensor in the tower head can serve as actual value pickup. The number of the deflecting means 23a, 23b is not limited to two, merely one deflecting means 23a, 23b or three deflecting means 23a, 23b can also be provided. For example, a combination of a rigid or braked deflecting means 23a, 23b and a freely rotatable deflecting pulley can also be provided.

Fig. 6 shows a portion of a tower 2 having a damping device 20 in an alternative configuration according to the invention. Due to the representation, the tower portion comprises merely two tower sections 3a and 3b. As is noticeable in Fig. 8, a force-absorbing element 11 and a feed-through unit 14 for fastening the upper portion of the steel cable 12 at an angle α (alpha) is provided in the upper portion of the second tower section 3b adjacent to the ring flange 9a on a tower fastening point (TAP). It is pointed out again that the steel cable 12, for example in the form of a spiral cable 12a and/or a round strand cable 12b, always has a certain sag which is not shown in Fig. 8 for the sake of simplicity. The lower portion of the steel cable 12 is held at an end of a pivot lever 25 of the damping apparatus 21 that is distant from a pivot axis. The pivot lever 25 is connected to the ballast mass 24 via a further portion of the steel cable 12 or a further short steel cable. The distance r from the fastening point of the steel cable 12 on the pivot lever 25 to the centre axis 2a of the tower 2 is variable and defines corresponding to the angular position γ (gamma) of the pivot lever 25, as one parameter of multiple parameters, the degree of damping or the damping effect of the damping device 20. On the end of the pivot lever 25 adjacent to the pivot axis there is a friction unit 26, wherein the mode of action of the friction unit 26 can be designed controllable or passive, semi-active or actively regulatable. The design configurations of the friction unit 26 for achieving a defined frictional force are manifold, for example the friction unit 26 in the simplest case can be formed as an adjustable disc brake, disc clutch or frictional disc clutch. In an improved configuration, the friction unit 26 comprises a plurality of sword-shaped or circular segment-shaped friction elements, which form at least one friction pairing, wherein at least one friction element is pivotably held on the pivot lever 25. The pivotable friction element dips between two stationary friction elements, which results in a different frictional force and thus damping effect. Transverse movements of the tower are introduced into the friction unit 26 via the pivot lever 25. In a control-oriented further development of the damping device 20, an acceleration and/or oscillation sensor is provided as an actual value pickup for a damping regulating circuit in the tower head, so that the frictional force of the friction unit 26 is controllable and/or regulatable in predeterminable limits.

Fig. 7 shows a schematic view of a feed-through unit 14 in the tower wall 10 according to the invention. The feed-through unit 14 initially comprises a force-absorbing element 11, in the exemplary embodiment formed as so-called load ring or load bracket 17, for example a "VLBG-PLUS load bracket" by the RUD company with a screw 27 and locking nuts 28. Furthermore, the feed-through unit 14 comprises a plate 30 as a counter bearing on the inside of the tower wall for the tensile force of the steel cable 12 or more precisely of the spiral cable 12a. The spiral cable 12a is connected, via a firmly connected clevis 32, to a bolt 33, via an oval ring 19 and a separable three-part connecting link 18 to the load bracket 17.

Fig. 8 shows a schematic view of a guide cable feed-through in the tower wall 10 with a wall feed-through 15b. A bush 29 is inserted in the upper wall feed-through 15b, through which a guide rope 16 runs. With the guide rope 16, the steel cable 12, more precisely the spiral cable 12a, is pulled according to the double arrow to the required height or upon the disassembly of the steel cable 12 lowered from the given height, so that the screw 27 of the load bracket 17 can be inserted into or securely removed from the provided lower wall feed-through 15a. In detail, the guide rope 16 is initially connected via a shackle 31 and the oval ring 19 to the clevis 32 of the spiral cable 12a. The load bracket 17 together with the screw 27 and the connection element 18 are suspended from the oval ring 19 during the lifting or lowering operation. In a modification of the method, the feed-through unit 14 was already assembled complete with the load bracket 17 and the plate 30 on the still horizontal tower section 3a, 3b, 3c, 3d, 3e on the erection site or in the manufacturing plant.

List of reference signs

1	Wind turbine
2	Tower
3a, 3b, 3c, 3d, 3e	Tower sections
4	Nacelle
5	Rotor
6	Rotor hub
8a, 8b	Rotor blades
9	Connection elements
9a	Ring flange
11	Force-absorbing element
12	Steel cable
12a	Spiral cable
12b	Round strand cable
13	Clamping connector
14	Feed-through unit
15a	Lower wall feed-through
15b	Upper wall feed-through
16	Guide rope
17	Load ring or load bracket
18	Connection element
19	Oval ring
20	Damping device
21	Damping apparatus
22	Steel frame
23	Deflecting unit
23a, 23b	Deflecting means
24	Ballast mass
25	Pivot lever
26	Friction unit
27	Screw
29	Bush

30	Plate
32	Clevis
33	Bolt
TAP	Tower connecting point
r	Distance from the axis of the first (upper) deflecting means 23a to the centre axis 2a of the tower 2
α	Angle
β	Overall wrap angle
β_1	Wrap angle of the first deflecting means 23a
β_2	Wrap angle of the second deflecting means 23b
γ	Angular position of the pivot lever 25

P A T E N T K R A V

1. Fremgangsmåde til dæmpning at svingninger af et tårn (2) til et vindenergianlæg (1) under opførelsen af tårnet (2) og vindenergianlægget (1), hvorved tårnet (2) omfatter en flerhed af tårnsektioner (3a, 3b, 3c, 3d, 3e), som hver især har et nederste og et øverste tilslutningselement (9), hvorved der på i det mindste en tårnsektion (3a, 3b, 3c, 3d, 3e) er anbragt i det mindste et kraftoptagelseselement (11), foretrukket to, særligt foretrukket fire kraftoptagelseselementer (11), foretrukket tilstødende til det øverste tilslutningselement (9), med trinene:

a) opførelse af et tårn (2) med en flerhed af tårnsektioner (3a, 3b, 3c, 3d, 3e),

b) fæstnelse af en første ende af en første stålwire (12), nemlig en spiralwire (12a), på det første kraftoptagelseselement (11) på en forudbestemt tårnsektion (3a, 3b, 3c, 3d, 3e),

c) forbindelse af den anden ende af den første stålwire (12) med en ende af en anden stålwire (12), nemlig en rundstrenget wire (12b),

d) føring af den anden stålwire (12) gennem en styreenhed (23) i en dæmpningsanordning (21) med i det mindste et styremiddel (23a, 23b), hvorved dæmpningsanordningen (21) er positioneret på en terrænoverflade uden for tårnet (2) og i en afstand fra tårnet (2),

e) forbindelse af den anden ende af den anden stålwire (12) med en ballastmasse (24) i dæmpningsanordningen (21).

2. Fremgangsmåde ifølge krav 1 med det yderligere trin, at før fæstnelsen af den første ende af den første stålwire (12) orienteres og/eller monteres kraftoptagelseselementet (11) på tårnsektionen (3a, 3b, 3c, 3d, 3e) i det væsentlige på tværs af en hovedvindretning.

3. Fremgangsmåde ifølge krav 1 eller 2 med det yderligere trin, at et andet kraftoptagelseselement (11) på tårnsektionen (3a, 3b, 3c, 3d, 3e) er anbragt eller monteret sådan, at dette er forskudt ca. 90° på tårnsektionens (3a, 3b, 3c, 3d, 3e) omkreds i forhold til positionen af det første kraftoptagelseselement (11).

4. Fremgangsmåde ifølge krav 3 med de yderligere trin:

k) fæstnelse af en første ende af en tredje stålwire (12), foretrukket en spiralwire (12a), på det andet kraftoptagelseselement (11) på tårnsektionen eller en yderligere tårnsektion (3a, 3b, 3c, 3d, 3e),

l) forbindelse af den anden ende af den tredje stålwire (12) med en ende af en fjerde stålwire (12), foretrukket en rundstrenget wire (12b),

m) føring af den fjerde stålwire (12) gennem en styreenhed (23) i en anden dæmpningsanordning (21) med i det mindste et styremiddel (23a, 23b),

n) forbindelse af den anden ende af den fjerde stålwire (12) med en ballastmasse (24) i den anden dæmpningsanordning (21).

5. Fremgangsmåde ifølge et af de foregående krav med det yderligere trin: positionering af den første dæmpningsanordning (21) i en sådan radial afstand fra tårnet (2), at stålwirens (12) vinkel til et horisontalt plan på dæmpningsanordningen (21) udgør 30° til 80°.

6. Fremgangsmåde ifølge krav 4 med det yderligere trin: positionering af den anden dæmpningsanordning (21) - relateret til tårnets (2) midterakse (2a) - forskudt ca. 90° i forhold til den første dæmpningsanordning (21) og i en sådan radial afstand fra tårnet (2), at den tredje stålwires (12) vinkel til et horisontalt plan på dæmpningsanordningen udgør (21) 30° til 80°.

7. Fremgangsmåde ifølge krav 4 med det yderligere trin: indstilling af den første og/eller anden dæmpningsanordning (21) til en forudbestemt dæmpningsværdi ved ændring af positionen af det i det mindste ene styremiddel (23a, 23b) sådan, at en samlet omslutningsvinkel *ß* (beta) og dermed friktionsmodstanden formindskes eller forøges, eller ved ændring af positionen af et første styremiddel (23a) og/eller et andet styremiddel (23b) sådan, at afstanden mellem det første styremiddel (23a) og det andet styremiddel (23b) og dermed den samlede omslutningsvinkel *ß* (beta) for stålwiren (12) og dermed friktionsmodstanden formindskes eller forøges, eller ved ændring af vinkelstillingen af en svingarm (25) på dæmpningsanordningen (21), hvilken svingarm står i virksom forbindelse med en indstillelig friktionsenhed (26) i dæmpningsanordningen (21).

8. Dæmpningsindretning (20) til gennemførelse af fremgangsmåden ifølge et af kravene 1 til 7 for et tårn (2) til et vindenergianlæg (1) med en flerhed af tårnsektioner (3a, 3b, 3c, 3d, 3e), omfattende en dæmpningsanordning (21), som omfatter et stativ (22), i hvilket der er lejret en styreenhed (23) og en ballastmasse (24), hvor dæmpningsanordningen (21) kan positioneres på en terrænoverflade uden for tårnet (2) og i en afstand fra tårnet (2), og omfattende en over styreenheden (23) ført stålwire (12), som på den ene side er forbundet med ballastmassen (24) og på den anden side med i det mindste et kraftoptagelseselement (11) på i det mindste en tårnsektion (3a, 3b, 3c, 3d, 3e), hvor styreenheden (23) har i det mindste et første styremiddel (23a, 23b), hvor det i det mindste ene styremiddel (23a, 23b) kan ændres i sin beliggenhed for at indstille dæmpningen, og hvor stålwiren (12) har et første afsnit, der er udformet som spiralwire (12a) og er fæstnet på tårnsektionens (3a, 3b, 3c, 3d, 3e) kraftoptagelseselement (11), og har et andet afsnit, der er udformet som rundstrenget wire (12b), som er ført over styreenheden (23) og er forbundet med dæmpningsanordningens (21) ballastmasse (24), hvor spiralwiren (12a) og den rundstrengede wire (12b) ved hjælp af en klemforbinder (13) er forbundet med hinanden, foretrukket løsbart.

9. Dæmpningsindretning (20) ifølge krav 8, kendetegnet ved, at spiralwiren (12a) på sin fra klemforbinderen (13) fjerntliggende ende har et fæstningselement, der er forbundet med kraftoptagelseselementet (11) på tårnsektionen (3a, 3b, 3c, 3d)

10. Dæmpningsindretning (20) ifølge et af kravene 8 til 9, kendetegnet ved, at den rundstrengede wire (12b) på sin fra klemforbinderen (13) fjerntliggende ende har et fæstningselement, der er forbundet med ballastmassen (24).

11. Dæmpningsindretning (20) ifølge et af kravene 8 til 10, kendetegnet ved, at dæmpningsindretningen (20) har et andet styremiddel (23b), hvor i det mindste et styremiddel (23a, 23b) er lejret forskydeligt i i det mindste et plan, fortrinsvis i to planer, hvorved en samlet omslutningsvinkel β (beta) for stålwiren (12) er indstillelig, foretrukket i området fra 10° til 240°.

12. Dæmpningsindretning (20) ifølge krav 11, kendetegnet ved, at den rundstrengede wire (12b) kan føres eller er ført over det første styremiddel (23a) og det andet styremiddel (23b), hvor styremidlerne (23a, 23b) i det mindste delvist har en konveks overflade af et materiale, som i forbindelse med en stålwire har en friktionskoefficient større end 0,3, foretrukket større end 0,4.

13. Dæmpningsindretning (20) ifølge krav 11 eller 12, kendetegnet ved, at det første og/eller det andet styremiddel (23a, 23b) er udformet som styrebjælke eller styrerulle, der kan bremses.

Drawings

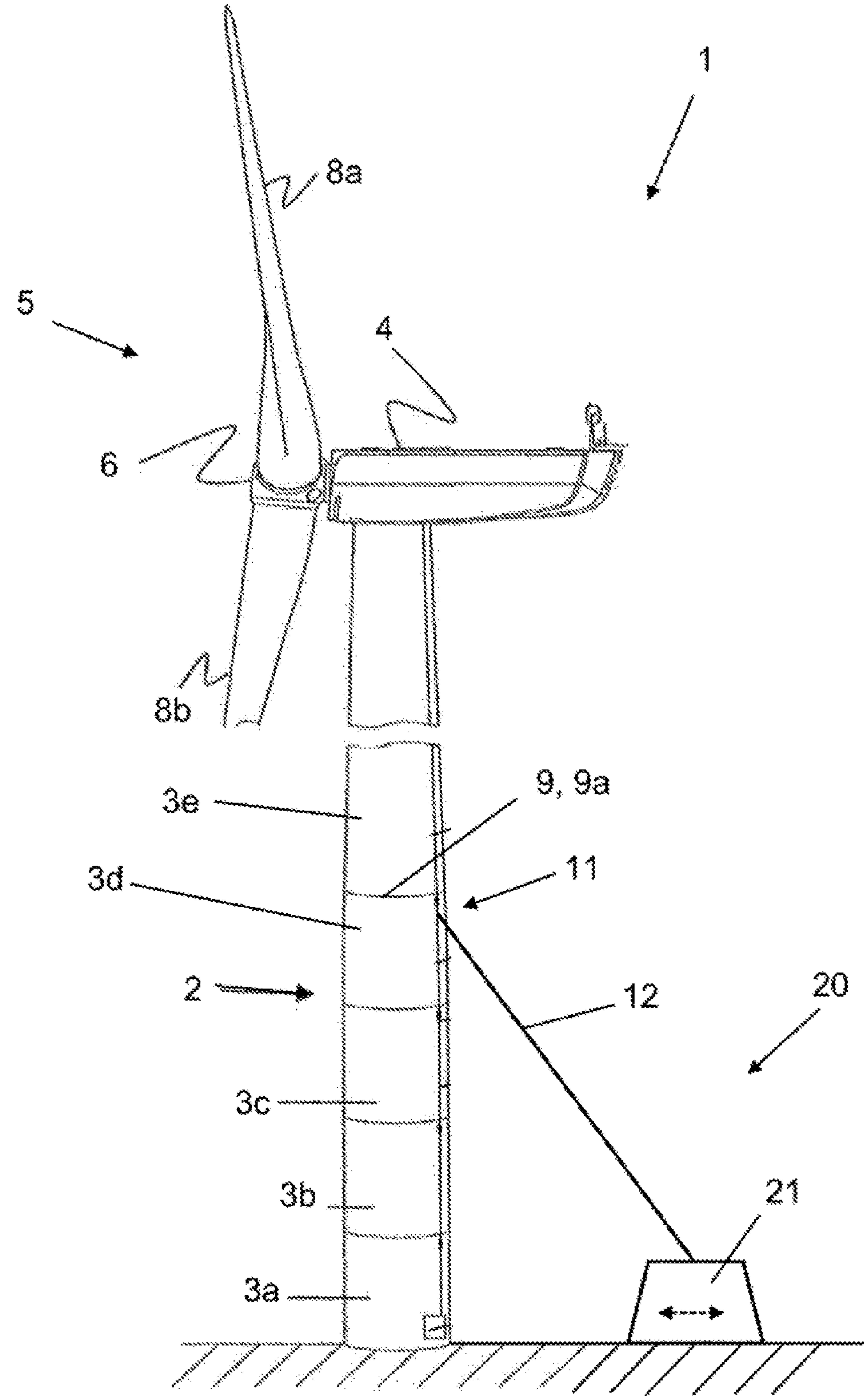

Figure 1

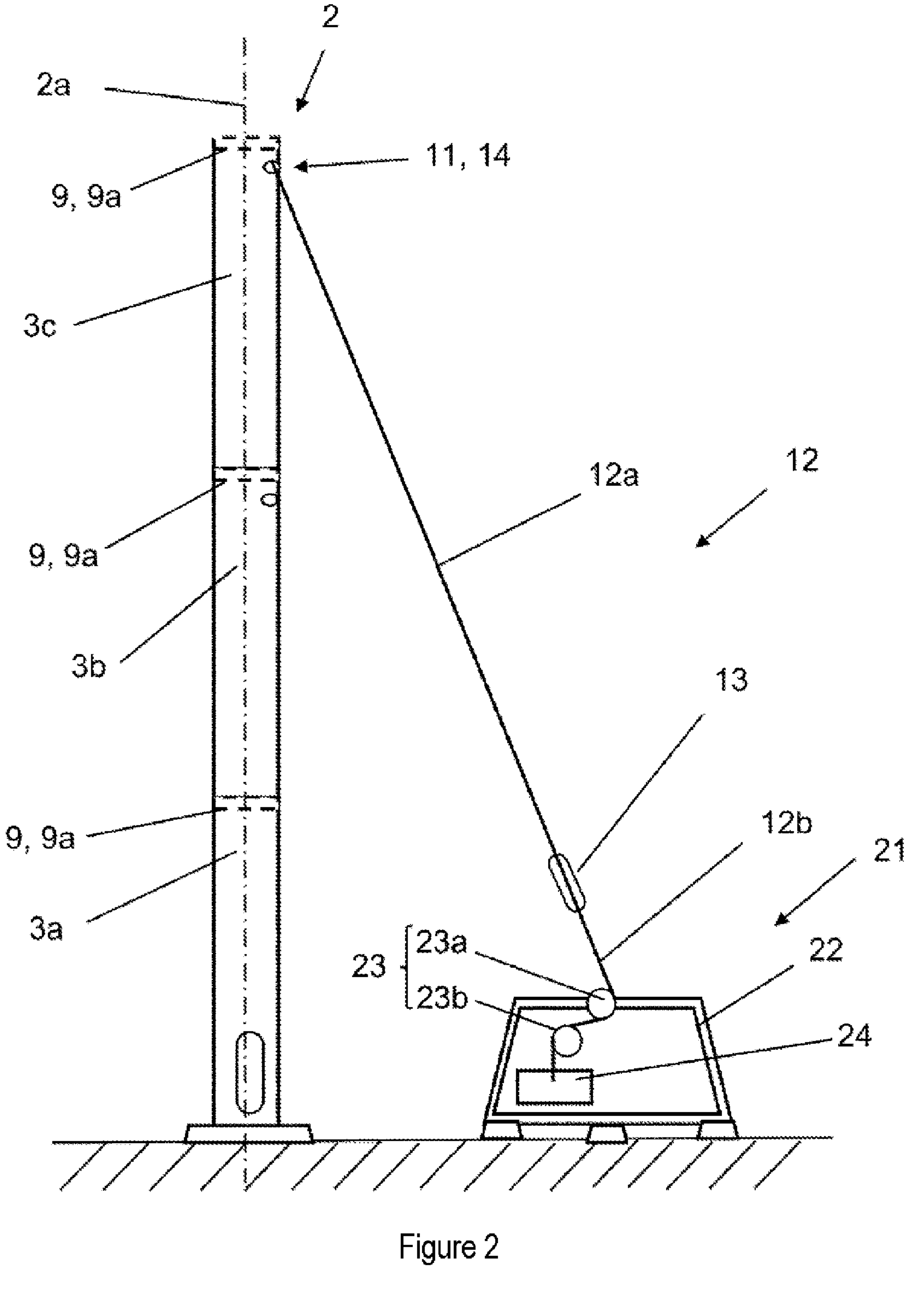

Figure 2

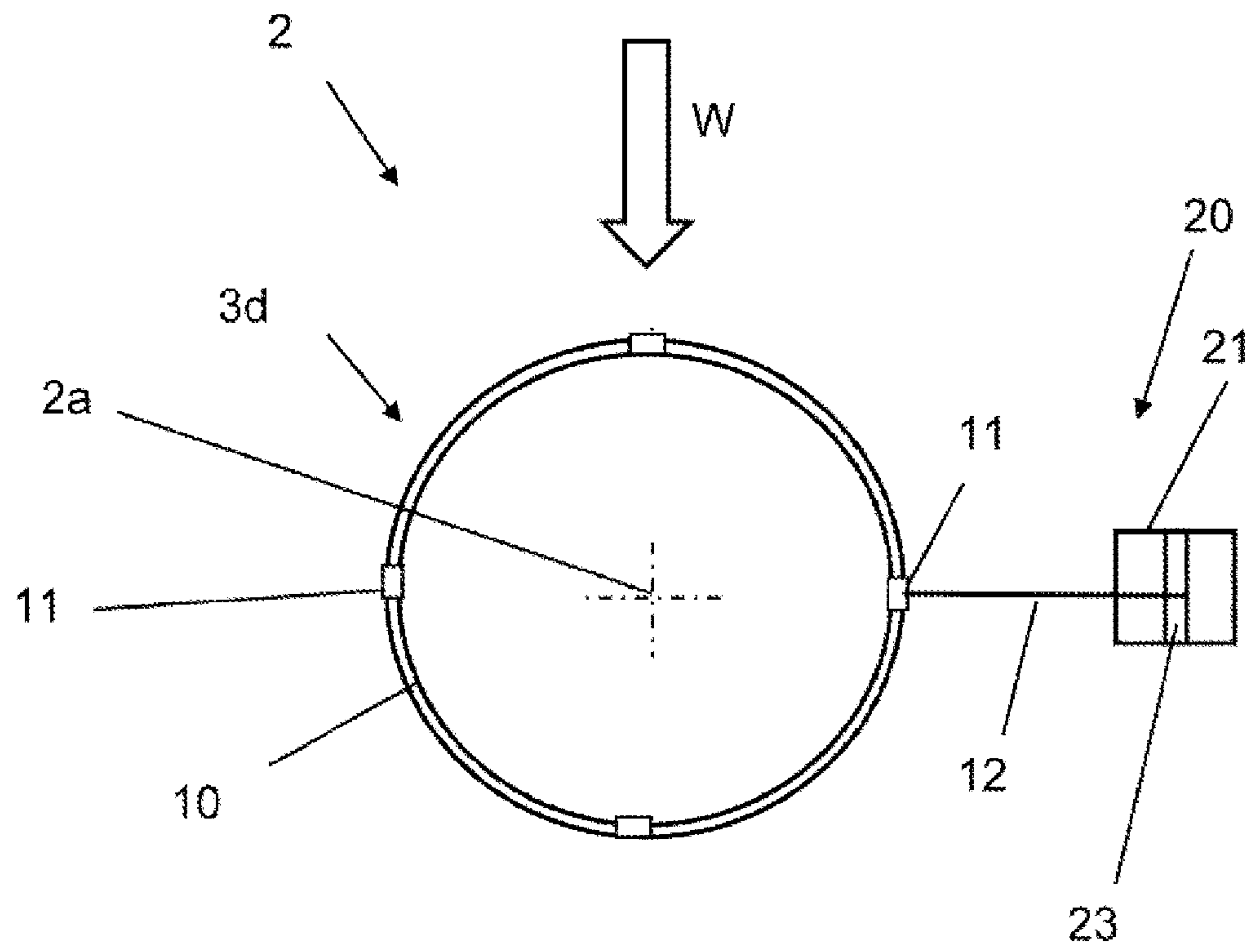

Figure 3

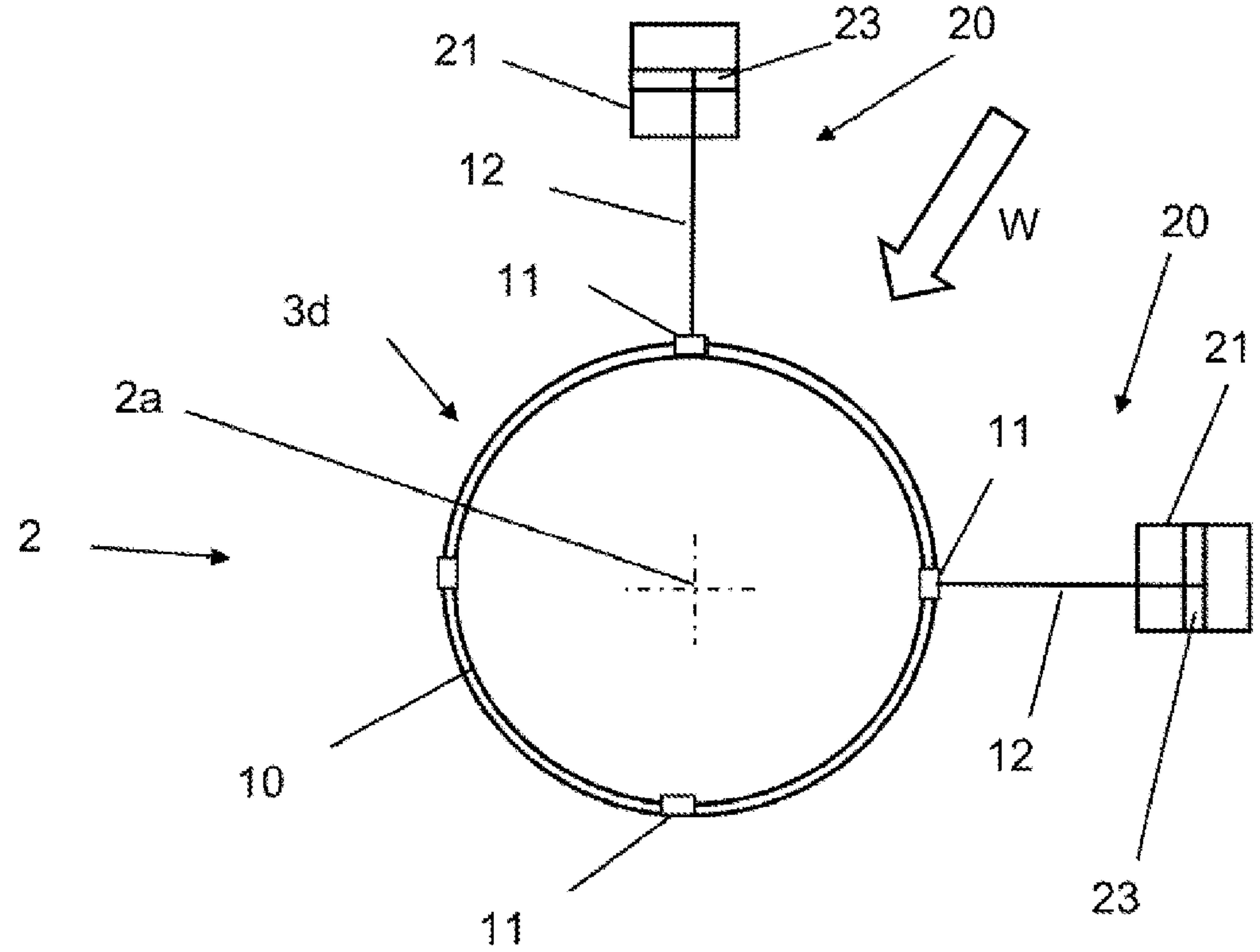

Figure 4

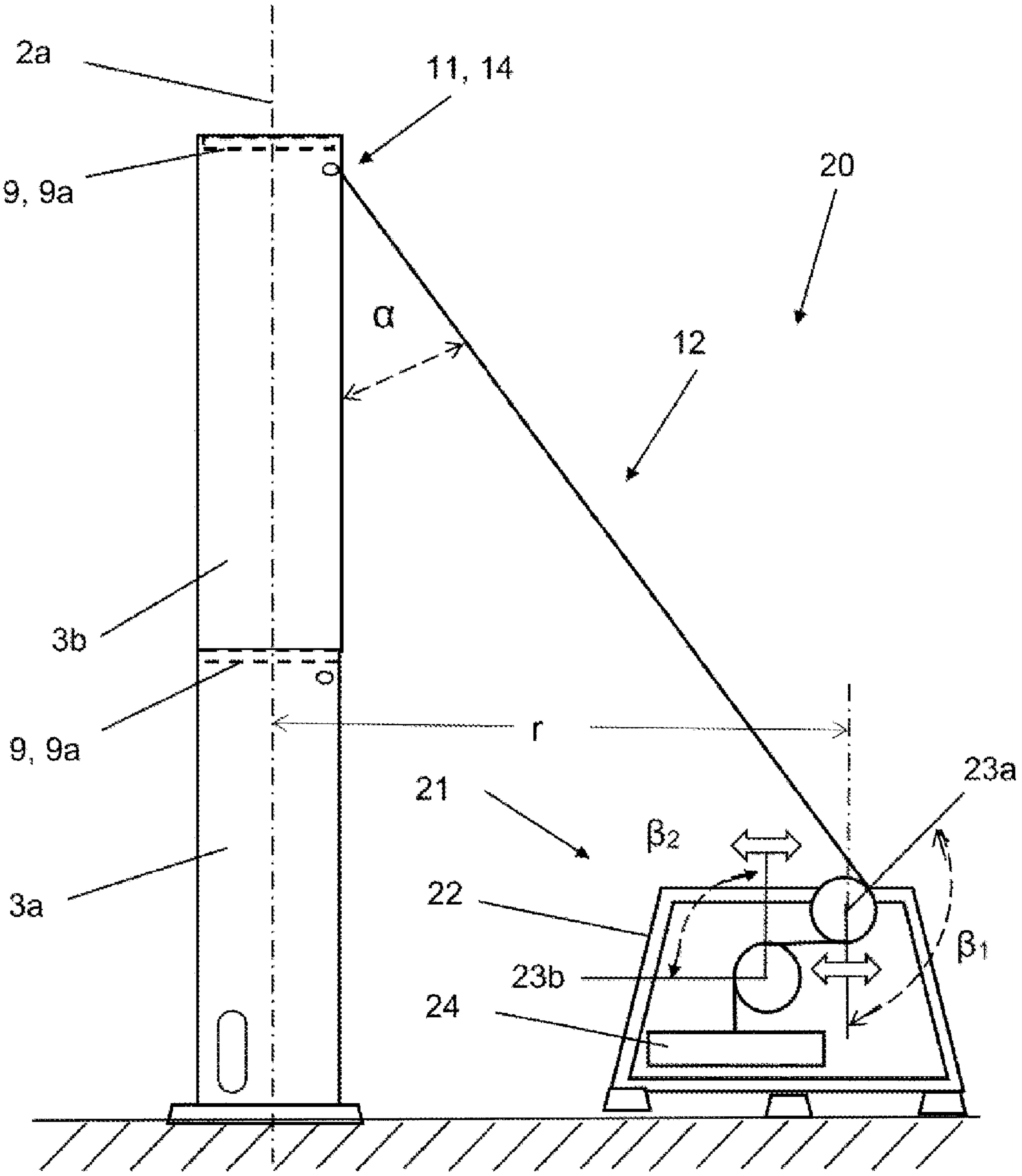

Figure 5

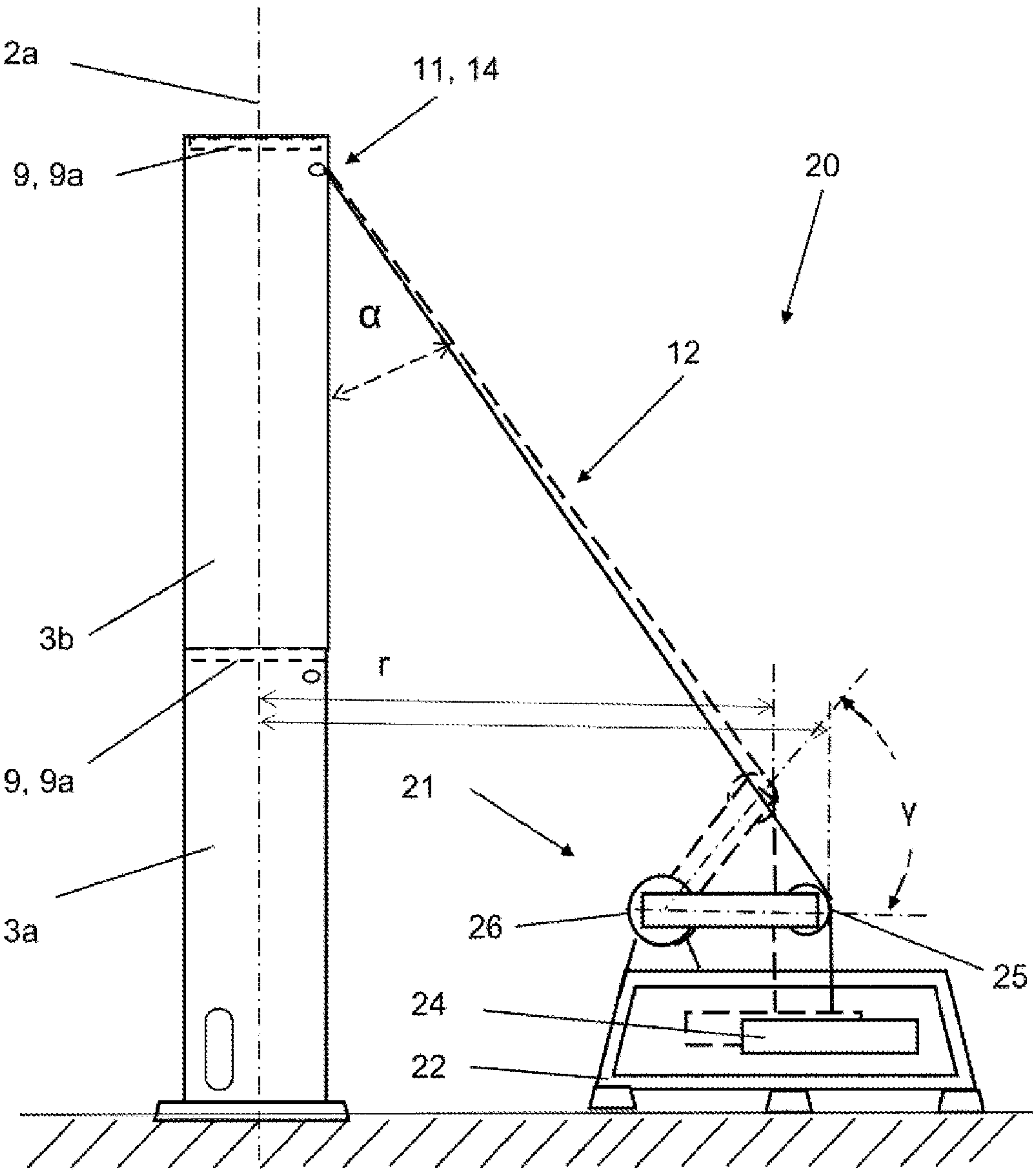

Figure 6

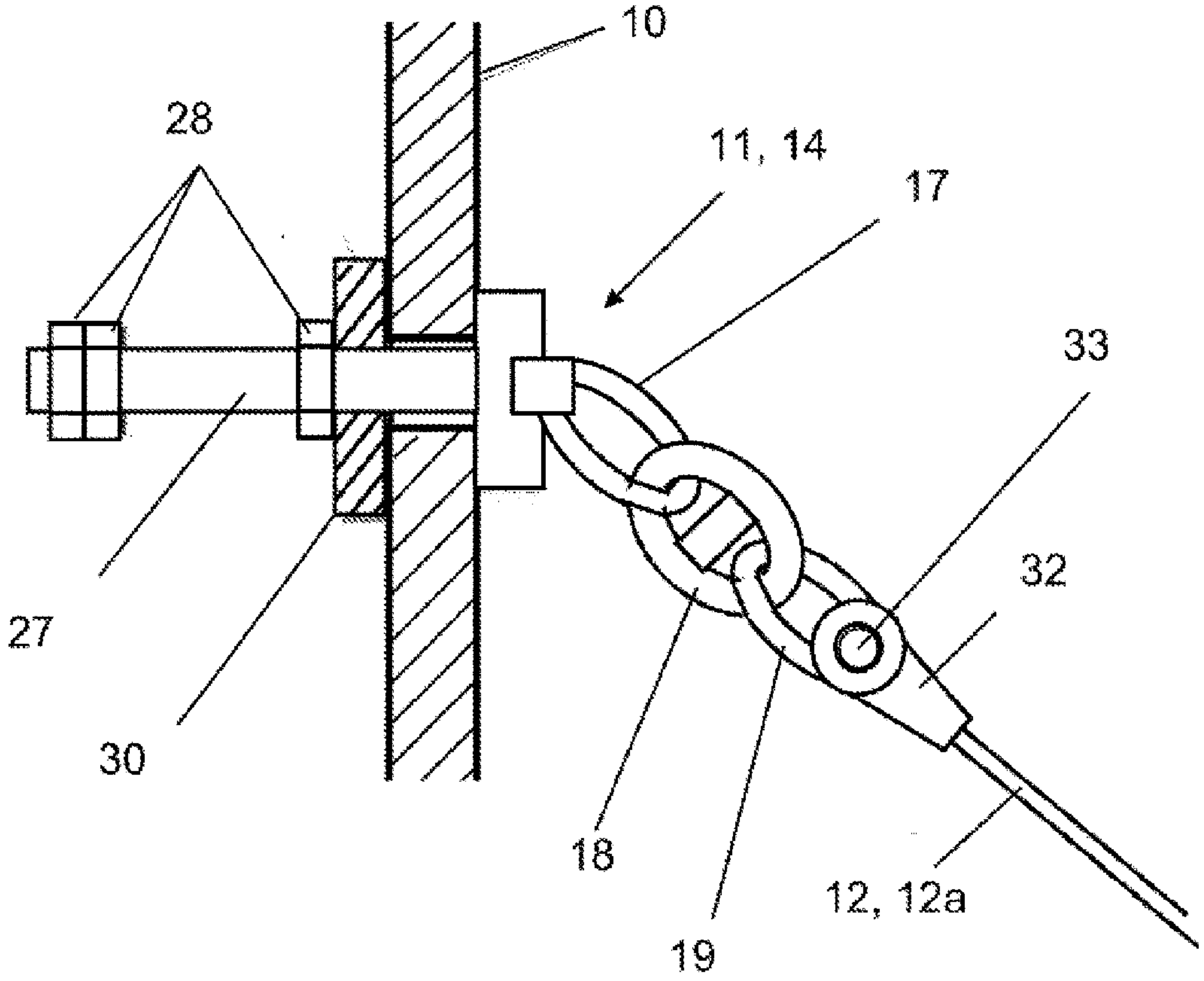

Figure 7

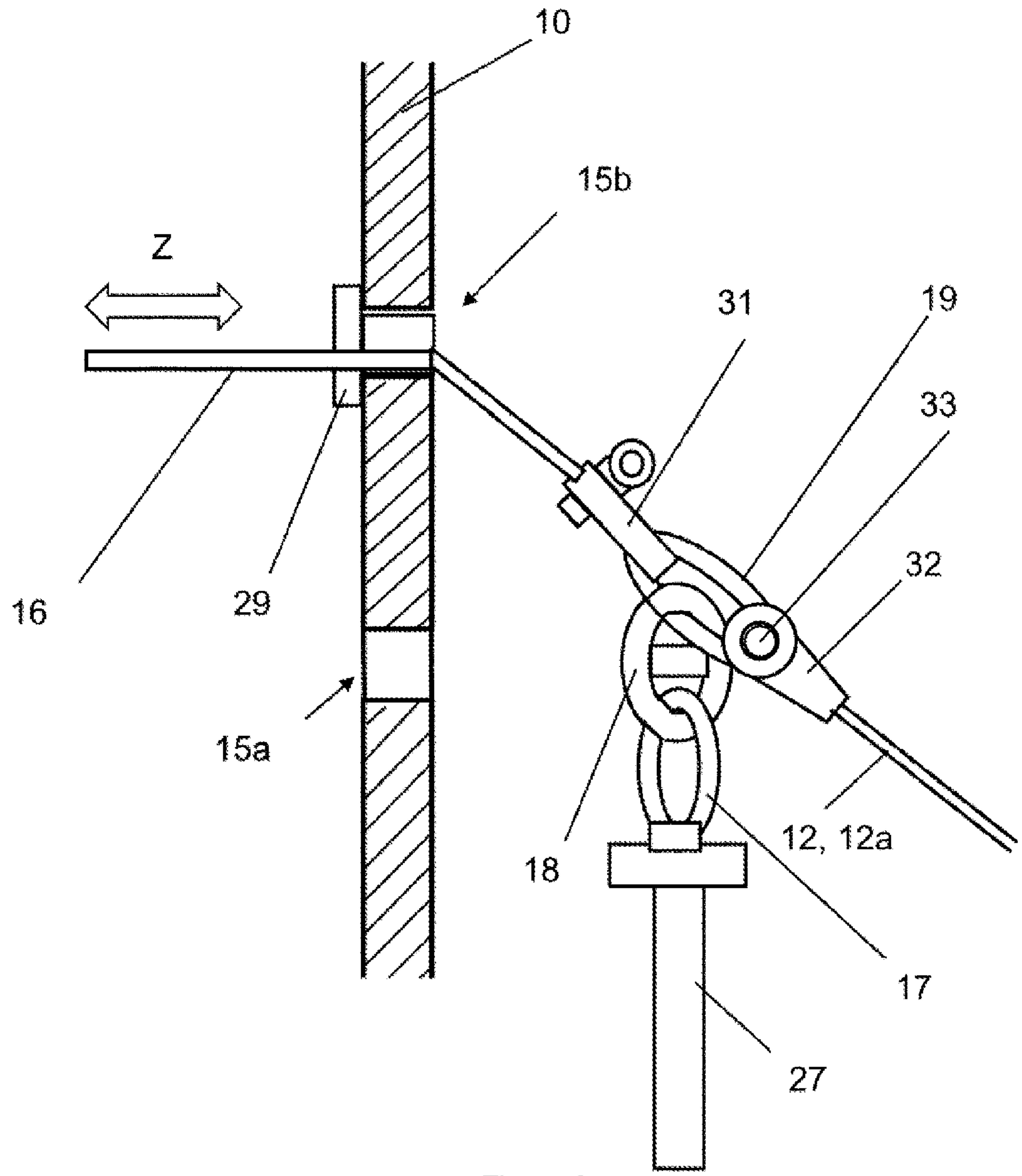

Figure 8