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- (73) Patenthaver: **FM Energie GmbH & Co. KG, Im Rosengarten 16, 64646 Heppenheim, Tyskland**
- (72) Opfinder: **MITSCH, Franz, Im Rosengarten 16, 64646 Heppenheim, Tyskland**
- (74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**
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## Wind turbines having elastic ball/pendulum bearings

The invention relates to wind turbines which, besides the usual devices for damping various vibrations occurring in the installation, are fitted with novel elastic ball/pendulum bearings. These ball/pendulum bearings can in principle be used for cardanic suspension of a pendulum absorber, preferably in the tower of a wind turbine, and also for attachment of the cable of floating offshore installations to the bottom of a body of water. The invention also relates to the corresponding equipped vibration pendulum absorbers as such which have additional damping devices for decreasing or reducing torsional vibrations of the pendulum, which may occur during oscillation of the pendulum, for example in the wind turbine, in particular on impact of the pendulum.

In accordance with the prior art (see, for example, EP 1 008 747 A2) pendulum bearings in wind turbines are usually suspended using shackles, which, apart from the frictional forces, do not themselves make any contribution to damping of the pendulum movement. Shackles of this type, which in their simplest embodiment are U-shaped bars which can be closed by means of a threaded or unthreaded bolt, are, however, subject to considerable wear, meaning that they must be subjected to constant monitoring, since there is a risk of the pendulum cable falling off together with the absorber mass with increasing operating time.

As an alternative to the said simple suspension, cardan joints have in the meantime also been used in the prior art, but these have the disadvantage of being relatively complex and expensive owing to their increased wear in the region of the sliding or roller bearings used.

Elastic pendulum joints have also occasionally been proposed in the prior art, but, in their known design proposals, they introduce great rigidity into the oscillation system, which is in principle undesired for use in wind turbines, so that, due to the known relatively great temperature dependence of the elastic materials, the resonant frequency of the absorber system is influenced and altered in an unforeseeable manner depending on the temperature. This in turn requires increased complex adaptation of the oscillation system.

The object was thus to provide a pendulum absorber, in particular for use in wind turbines, having a suspension or joint bearing which has improved properties in the said respect compared with the known solutions from the prior art, where importance should be attached, in

particular, to high axial strength, a low restoring moment, and a highly insignificant influence on the resonant frequency of the system and thus on substantial temperature independence.

The object set has been achieved by the subject-matters of the invention specified and described below and in the claims.

5 The invention thus relates to a wind turbine comprising at least one elastic bearing which is a ball/pendulum bearing, which in turn comprises a ball joint (5) having an inner joint head (5.4) and a joint socket (5.5), where the joint head has an at least hemispherical shape and is mounted in the corresponding dimensioned and shaped joint socket, and at least one, preferably two or three elastomer layers (5.1) are arranged between joint head and joint socket in  
10 such a way that at least 80%, preferably 90 – 100% of the area of the elastomer layer is firmly connected to the spherical areas of the joint head and joint socket, and the elastomer layer has a thickness of 5 mm – 20 mm, where, in the case of the presence of a plurality of elastomer layers, these are completely or partially separated from one another by intermediate metal sheets (5.3).

15 In a preferred embodiment of the invention, the said ball/pendulum joint or bearing has two elastomer layers which are separated from one another by a metal sheet, which is preferably interrupted in the central region of the elastomer layer (Fig. 4d)

It has been found that such joint heads and corresponding joint sockets which have at least a hemispherical shape, but preferably a part-spherical shape with a circle radius or wrap angle  
20 of 180° to 325°, preferably 180° to 245°, or 220° to 245°, should advantageously be employed, where if possible the entire spherical surfaces are covered with an elastomer layer. Only in the case of this design measure is the pendulum bearing able to move through large angles in a small space while accommodating large forces without the resonant frequency of the system, or of the wind turbine, being significantly influenced.

25 In a particular embodiment of the invention, the elastomer layer (5.1) between the spherical joint head (5.4) and the spherical joint socket (5.5) may have different stiffness, in particular with respect to the axial orientation of the pendulum and the horizontal orientation of the pendulum perpendicular thereto, or in other words with respect to the centre of the respective sphere compared with the edges. This can be achieved in accordance with the invention by

two measures. On the one hand, the elastomer material can be of different stiffness at the point in question, or the regions in question, so that the deflection properties of the pendulum can be influenced thereby without the damping properties of the pendulum absorber changing significantly at the same time. Different stiffnesses can be achieved, for example, by the use  
5 of elastomer material having different Shore hardness.

On the other hand, it may be provided that the elastomer material contains specifically positioned (for example at the zenith of the joint head sphere) chambers which can be filled from the outside with a fluid under pressure via a valve (Fig. 4b, c). The fluid serves for the formation of a cavity and the element thereby becomes softer in the cardanic direction. The ele-  
10 ment under load does not become stiffer due to the higher pressure.

The chambers may also in principle form due to the injection of fluid in a region in which elastomer layer and metal of the joint bearing are not firmly connected to one another, or in with a region inside the elastomer layer in which elastomer material only lies on one another and can be stretched under pressure to form a chamber.

15 The invention furthermore relates to a corresponding wind turbine in which the ball/pendulum bearing is part of a pendulum vibration absorber which comprises a pendulum rod (2) and an absorber mass (1), where the pendulum absorber is able to move freely in all directions around the elastic ball/pendulum bearing, and preferably has a device in the region of the ball/pendulum bearing which reduces or prevents torsional vibrations of the absorber.

20 In a first embodiment of this type (Figs. 1 – 3), the said device comprises at least one torsion lever (2.1), which is mounted essentially perpendicular to the pendulum rod (2) and has an elastic torsion bearing for pitch movements (6) and an elastic torsion bearing for rotational movements (7) of the pendulum (1, 2). For better load distribution, a plurality of such torsion levers, preferably three, may also be provided.

25 In a further embodiment of the invention, the device comprises at least three spring elements (8), which are distributed essentially uniformly around the pendulum rod (2) in the region of the pendulum joint (5) and are arranged in such a way that torsional movements of the pendulum (2) can be damped or prevented (Fig. 5). The spring elements here can be conventional coil springs or elastic springs comprising layers of elastomer material and intermediate

metal sheets. It is furthermore also possible to use hydraulic dampers. Three such elements with spring direction are preferably arranged perpendicular to the axis of the pendulum absorber in the region of the pendulum joint, preferably around, above or below the latter, preferably in such a way that they form a 120° angle to one another. In this way, the spring forces acting are able to prevent or reduce torsion of the pendulum absorber by the latter striking the tower wall or a stop device provided for this purpose.

Essentially the same effect is achieved by the further embodiment according to the invention of Fig. 6, which is arranged in a similar manner. In this case, use is made of a device in this respect which has at least three connecting rods (9) with elastic spherical bearings (9.1)(9.2), which are distributed essentially uniformly around the pendulum rod (2) in the region of the pendulum joint (5) and are arranged in such a way that torsional movements of the pendulum (2) are damped or prevented. The connecting rods (9) can be realised, for example, as depicted in Fig. 6, by roller elements.

In a very specific simple embodiment of the invention, the device for damping torsional movements of the pendulum comprises a pendulum yoke (2.2)(2.3) having elastic stop elements (10) in the region of the pendulum joint (5), as depicted, for example, in Fig. 7.

In further embodiment of the invention, the said devices for damping the torsional movement of the pendulum can be formed by combinations of the said embodiments. In particular, the use of a pendulum yoke can be combined with a spring device or a connecting rod device.

The described pendulum joints according to the invention are also eminently suitable for use in offshore platforms of various use, for example wind turbines or oil rigs for movable attachment of the platform to the sea-bed. The invention thus also relates to an offshore platform (18), in particular for wind turbines, which is anchored via cables (15) to the sea or ocean bed (12) via foundations (11), with each cable (15) being attached, by means of cable attachments (14), to the platform via a said upper ball joint (17) according to the invention and to the foundation via a said lower ball joint (16) according to the invention. An application of this type is depicted in Fig. 8.

The invention also relates to a corresponding pendulum vibration absorber, comprising a pendulum rod (2) or pendulum cable, at least one absorber mass (1) and an elastic ball joint (5) at the upper end of the pendulum rod/pendulum cable, where

- (i) the ball joint (5) is fitted with an inner joint head (5.4) and a joint socket (5.5),
- 5 (ii) the joint head has an at least hemispherical shape and is mounted in the corresponding dimensioned and shaped joint socket,
- (iii) at least one, preferably two, elastomer layers (5.1) separated by a metal sheet is/are arranged between joint head and joint socket, so that the pendulum is able to move freely in all directions around the elastic ball/pendulum bearing,
- 10 (iv) the joint head (5.4) connected to the elastomer layer and the corresponding joint socket (5.5) have a part-spherical shape with a circle radius or wrap angle of  $180^\circ$  to  $325^\circ$ , preferably greater than  $220^\circ$ , in particular greater than  $245^\circ$ , but not greater than  $325^\circ$ , and
- (v) a device which reduces or prevents axial torsional vibrations of the pendulum is installed in the region of the ball joint (5), where the device additionally
- 15 (i) comprises at least one torsion lever (2.1) which is installed essentially perpendicular to the pendulum rod (2) and has an elastic torsion bearing for pitch movements (6) and an elastic torsion bearing for axial rotational movements (7) of the pendulum (1, 2), or
- (ii) has at least three spring elements (8) which are distributed essentially uniformly around the pendulum rod (2) in the region of the pendulum joint (5) and are arranged in such a way that torsional movements of the pendulum (2) are damped or prevented, or
- 20 (iii) has at least three connecting rods (9) with elastic spherical bearings (9.1, 9.2) which are distributed essentially uniformly around the pendulum rod (2) in the region of the pendulum joint (5) and are arranged in such a way that torsional movements of the pendulum (2) are damped or prevented, or
- 25 (iv) has a pendulum yoke (2.2)(2.3) having elastic stop elements (10) in the region of the pendulum joint (5) and is arranged in such a way that torsional pendulum movements are damped or prevented, or
- (v) comprises combinations of the device elements from (ii) to (iv), in particular (ii) and (iv), or (iii) and (iv).
- 30 Finally, the invention also relates to wind turbines and pendulum vibration absorbers which, apart from the torsion damping elements described, additionally have damping elements which are capable of damping the various vibrations occurring in the installation. These can

be prior-art eddy current dampers, hydraulic dampers or other temperature-independent dampers (e.g. WO 2013/023728, WO 2014/102016, WO 2016/023628).

The reference numerals used in the figures, in the text and in the claims are described briefly below:

5

- |    |       |                                           |
|----|-------|-------------------------------------------|
|    | 1     | absorber mass                             |
|    | 2     | pendulum rod                              |
|    | 2.1   | torsion lever                             |
|    | 2.2   | pendulum yoke                             |
| 10 | 2.3   | upper attachment                          |
|    | 2.4   | pendulum rod connection                   |
|    | 3     | attachment construction                   |
|    | 4     | pendulum element with rotation inhibition |
|    | 5     | semi-ball joint                           |
| 15 | 5.1   | inner elastomer layer                     |
|    | 5.2   | outer elastomer layer                     |
|    | 5.3   | intermediate metal sheet                  |
|    | 5.4   | inner ball                                |
|    | 5.5   | outer ball                                |
| 20 | 5.6   | fluid                                     |
|    | 5.7   | sealing bead                              |
|    | 5.8   | filling valve                             |
|    | 6     | pitch torsion bearing                     |
|    | 7     | rotation torsion bearing                  |
| 25 | 8     | torsion spring element                    |
|    | 9     | connecting rod                            |
|    | 9.1   | spherical bearing in connecting rod       |
|    | 9.1.1 | spherical elastomer track                 |
|    | 10    | stop buffer                               |
| 30 | 11    | foundation anchor                         |
|    | 12    | sea bed                                   |
|    | 13    | water                                     |
|    | 14    | cable attachment                          |
|    | 15    | cable                                     |
| 35 | 16    | joint lower                               |
|    | 17    | joint upper                               |
|    | 18    | offshore platform                         |
|    | 19    | movable yoke                              |
|    | 20    | fixed yoke                                |

40 Further details of the invention are described below, in particular, with reference to Figures 1 – 10:

The absorber system described has a low restoration moment at the same time as high axial strength, so that the influence of the elastomer on the resonant frequency has only a very

insignificant influence on the resonant frequency of the system and thus the temperature dependence also becomes negligibly small.

This property is achieved by one or more hemispherical elastomer layers stacked one above the other. Owing to the large sphere envelope surface area and the particularly thin layers,  
5 high axial stiffnesses are thus achieved, which enables the transmission of correspondingly large axial forces.

The ratio of the axial stiffness to the torsional stiffness increases with increasing wrap angle, which is why wrap angles of the ball elements of greater than  $220^\circ$ , in particular between  $220^\circ$  and  $325^\circ$ , or  $220^\circ$  and  $245^\circ$  are particularly suitable. An embodiment of this type is  
10 depicted in [Fig. 10](#). Ball elements having an angle up to about  $225^\circ$  can still be manufactured as a single part. In the case of larger wrap angles, they are generally composed of two or more parts. The elastomer layer is pulled as far as possible around the ball radius in order to keep the ratio of free rubber surface to metal-bonded rubber surface as small as possible. Depending on the requirements of the possible rotation angle, as many elastomer layers as  
15 desired can be connected one behind the other.

The cardanic stiffness of the absorber can be reduced further by introduction of a fluid (5.6), since no elastomer deformation takes place in the region of the fluid. The elastomer deformation only takes place in the region outside the fluid, so that only a relatively small elastomer region is deformed, which causes lower push forces and thus lower cardanic forces. As  
20 depicted in [Fig. 4b](#), a sealing bead (5.7) prevents the ingress of the fluid into the space between metal and elastomer. As generally known, liquid tends to accumulate in the rubber-metal bond in the form of extremely small droplets when the pressure is released and penetrate deeper into the bond during the next loading, meaning that the liquid may escape in the case of frequent loading. This can be prevented, for example, by employing a thick liquid, for  
25 example viscous silicone, instead of water.

A conventional pendulum absorber usually has an absorber mass which strikes the wall of the tower of the wind turbine via a stop system. In this case, it may occur that the absorber strikes the curvature tangentially and thus experiences a relatively large torsion moment. This torsion moment is transmitted to the ball joint via the pendulum rod. However, the ball joint

has only low torsional stiffness, meaning that it is necessary to absorb this by means of a further construction. The angle of rotation of the absorber must not be too great here in order not to stress the connection to the dampers. The solution according to the invention is depicted in Figs. 1 to 3.

5 Fig. 1 shows a pendulum absorber consisting of the absorber mass (1), the pendulum rod (2), an attachment construction (3) and the pendulum element with rotation inhibition (4). The moment is transmitted via the torsion lever (2.1). The torsion lever is connected to the pendulum yoke (2.2) in an articulated manner. The point of rotation of this connection is advantageously at the same height as the point of rotation of the ball/pendulum bearing. This connection can  
10 be established, for example, in the form of sliding bearings. Elastomer bushes (6) are preferably used here. The end of the torsion lever merges into a rotation torsion bearing (7), which is arranged perpendicular to the pitch torsion bearings (6). This bearing is in the form of an elastomer bearing in order that it is able to transmit both a torsion load and also a cardanic load. It is possible to design the system, as depicted, with a torsion lever (2.1). In order to  
15 enable better load distribution, two or more, preferably three, such levers may also be provided on the periphery.

As an alternative to one or more torsion levers, as described, it is also possible to employ spring elements or elastic elements, as shown in Fig. 5 and Fig. 6. The semi-ball joint (5) of Fig. 5 is constructed here as described above. In order to absorb the torsional impacts, a  
20 plurality of tangentially arranged multilayered torsion spring elements (8) are installed in the region of the joint. These connect the pendulum yoke (2.2) to the upper attachment (2.3). Detonation spring elements (8) thus establish an elastic connection to the elements (2.2) and (2.3). This connection is soft in the pendulum direction owing to the low shear stiffness of multilayered elements of this type. Owing to the relatively high axial stiffness of the multi-  
25 layered torsion spring elements, there is high stiffness in the torsion direction between (2.2) and (2.3). The system of Fig. 6 has a similar construction to the embodiment in accordance with Fig. 5. However, the upper attachment (2.3) is connected to the pendulum yoke (2.2) by connecting rods (9). This likewise gives rise to a torsionally stiff and cardanically soft connection between pendulum yoke (2.2) and the upper attachment (2.3). The connecting rods (9)  
30 consist, for example, of two elastomer spherical bearings (9.1) or roller elements, which are

known per se in the prior art. These have the property of being radially stiff and relatively soft in the cardanic direction.

The embodiment in accordance with Fig. 7 essentially consists of a semi-ball joint (5), the pendulum yoke (2.2) with the upper attachment (2.3). The torsion forces occurring due to the tangential striking of the absorber are transmitted via stop buffers (10).

A completely different application for the elastic ball/pendulum bearings is the connection and attachment of offshore platforms, in particular in connection with wind turbines or possibly other floating installations (Fig. 8, Fig. 9). The bearing can thus be employed both for offshore platforms as such and for offshore platforms with wind turbines in particular. When attaching the cables of offshore foundations, the problem exists that the cables kink at the fixing site owing to cardanic movement. This can be remedied by the use of commercially available shackles. However, these are subject to considerable wear owing to the friction arising between the individual elements, meaning that they are only serviceable for a limited period. On use of the elastomer ball/pendulum bearing according to the invention, the transition takes place in a friction-free manner. The elements are maintenance-free over a long period. An elastomer ball/pendulum bearing (5) having one or more hemispherical elastomer layers is also used here. These are positioned between the movable yoke (19) and the fixed yoke (20). The cable attachment (14) (Fig. 9) is installed on the respective movable yoke (20). Owing to the low cardanic stiffness of the elastomer elements, the cable is only subjected to low flexural moments. The kink loading on the cable is low. Elements of this type in accordance with the invention are able to transmit loads of greater than 1000 kN, even with a diameter of about 200 mm, at the same time as low cardanic stiffness. The cardanic stiffness can be reduced further here through the use of a fluid (56) in accordance with an arrangement as shown in Fig. 4b,c. If two elastomer layers are used, a fluid cushion can also be introduced on the inner ball, enabling the cardanic stiffness to be reduced further on the one hand through a plurality of layers and at the same time by the use of the fluid cushion. In order to facilitate even greater angles with a low restoration force, a plurality of joints can be connected one behind the other. For this purpose, it is sensible to design the elements that are further from the foundation or platform to be softer in the direction of the cable than the elements of the fixing site. In the case of correspondingly soft connection points, the cable

technology can be omitted entirely. The cables can be replaced by a succession of several joints with rigid elements connected in between.

The elastomer layers in the ball/pendulum bearings according to the invention can have different thicknesses, which, however, vary predominantly between 5 mm and 20 mm. If two  
5 layers are used, the inner layer advantageously has only about 50 – 70% of the thickness of the outer layer, which is vulcanised to the joint socket. An elastic inner layer has a thickness of between 4.5 and 9 mm, whereas an elastic outer layer can have a thickness of between 6 and 12 mm. The Shore hardnesses of the elastomers used in the ball/pendulum bearings according to the invention can be between 50 and 100 Shore A.

**Patentkrav**

- 1.** Vindmølle omfattende en pendul-svingningsdæmper med høj aksial styrke, som er i stand til at optage store kræfter, gennemløbe store vinkler på ringe plads og  
5 bevæge sig frit i alle retninger uden væsentlig påvirkning af anlæggets egenfrekvens, idet svingningsdæmperen omfatter en pendulstang (2), en dæmpningsmasse (1) og mindst et kuglependulleje, som er anbragt på pendulstangens (2) øverste ende, og et elastisk kugleled (5) med et indre ledhoved (5.4) og en ledpande (5.5), idet ledhovedet er lejret i den tilsvarende  
10 dimensionerede og formede ledpande, idet det elastiske kugleleds (5) ledhoved (5.4) og ledpande (5.5) er sfæriske, og ledhovedets (5.4) og ledpandens (5.5) samlede sfæriske flader er dækket af mindst et elastomerlag (5.1) og gennem dette er fast forbundet med hinanden, idet det mindst ene elastomerlag har en tykkelse fra 5 til 20 mm, og de af elastomerlaget dækkede samlede sfæriske  
15 flader på ledhovedet (5.4) og ledpanden (5.5) har en delkugleform med en omviklingsvinkel fra 180° til 325°.
- 2.** Vindmølle ifølge krav 1, **kendetegnet ved, at** kuglependullejet har mindst to elastomerlag (5.1, 5.2), som helt eller delvis er adskilt fra hinanden gennem en  
20 eller flere mellemlager (5.3).
- 3.** Vindmølle ifølge krav 1 eller 2, **kendetegnet ved, at** lejet har områder mellem elastomerlag (5.1) og ledhoved (5.4) og / eller ledpande (5.5) eller inden for elastomerlaget (5.1), som tillader, at et fluid (5.6) gennem en fyldeventil kan  
25 presses ind i disse områder, således at der derved foreligger lokalt forskellige torsionsstivheder ved konstante aksiale stivheder.
- 4.** Vindmølle ifølge et af kravene 1 til 3, **kendetegnet ved, at** elastomerlaget (5.1) mellem ledhoved og ledpande har en forskellig stivhed i lejets aksiale  
30 retning og i dets vandrette retning.
- 5.** Vindmølle ifølge et af kravene 1 til 4, **kendetegnet ved, at** svingningsdæmperen har et apparat i kuglependullejets område, som formindsker

eller forhindrer dæmperens torsionssvingninger.

**6.** Vindmølle ifølge krav 5, **kendetegnet ved, at** apparatet omfatter mindst en torsionsarm (2.1), som er anbragt i det væsentlige vinkelret på pendulstangen (2) eller pendulkablet (14) og har et elastisk torsionsleje til pendulets (1, 2) huggebevægelser (6) og et elastisk torsionsleje til dets drejebevægelser (7).

**7.** Vindmølle ifølge krav 5, **kendetegnet ved, at** apparatet har et pendullåg (2.2) (2.3) med elastiske anslagselementer (10) i pendulledets (5) eller pendulkablets (14) område og er anbragt således, at torsionsbevægelser af pendulet dæmpes eller undgås.

**8.** Vindmølle ifølge krav 5 eller 7, **kendetegnet ved, at** apparatet har mindst tre fjederelementer (8), som i pendulledets (5) område er fordelt i det væsentlige ensartet omkring pendulstangen (2) eller pendulkablet (14) og er anbragt således, at torsionsbevægelser af pendulet dæmpes eller undgås.

**9.** Vindmølle ifølge krav 5 eller 7, **kendetegnet ved, at** apparatet har mindst tre styrestænger (9) med elastiske sfæriske lejer (9.1)(9.2), som i pendulledets (5) område er fordelt i det væsentlige ensartet omkring pendulstangen (2) eller pendulkablet (14) og er anbragt således, at torsionsbevægelser af pendulet dæmpes eller undgås.

**10.** Vindmølle ifølge et af kravene 1 til 9, **kendetegnet ved, at** den har mindst et yderligere apparat til dæmpning af i møllen optrædende svingninger, idet dette apparat er en hydraulisk dæmper, en hvirvelstrømsdæmper eller en mekanisk temperaturuafhængig dæmper.

**11.** Vindmølle ifølge et af kravene 1 til 10, **kendetegnet ved, at** vindmøllen er en offshore-platform (18), som gennem kabler (15) er forankret til hav- eller søbunden (12) over fundamenter (11), idet hvert kabel (15) ved hjælp af kabelfortøjninger (14) er fastgjort til platformen gennem et omtalt kugleled (5) som øvre kugleled (17) og til fundamentet gennem et omtalt kugleled (5) som nedre kugleled (16).

**12.** Vindmølle omfattende mindst et elastisk kuglependulleje, som omfatter et kugleled (5) med et indre ledhoved (5.4) og en ledpande (5.5), idet ledhovedet har mindst halvkugleform og er lejret i den tilsvarende dimensionerede og formede ledpande, **kendetegnet ved, at** der mellem ledhoved og ledpande er  
5 anbragt mindst to elastomerlag (5.1, 5.2), som helt eller delvis er adskilt fra hinanden gennem en eller flere mellemlader (5.3), således at mindst 80% af et elastomerlags areal er fast forbundet med ledhovedets og ledpandens sfæriske flader, et elastomerlag har en tykkelse fra 5 mm til 20 mm, og det af et elastomerlag dækkede ledhoved (5.4) og den tilsvarende ledpande (5.5) har en  
10 delkugleform med en omviklingsvinkel fra 180° til 325°.

**13.** Vindmølle ifølge krav 12, **kendetegnet ved, at** vindmøllen er en offshore-platform (18), som gennem kabler (15) er forankret til hav- eller søbunden (12) over fundamenter (11), idet hvert kabel (15) ved hjælp af kabelfortøjninger (14)  
15 er fastgjort til platformen gennem et omtalt kugleled (5) som øvre kugleled (17) og til fundamentet et omtalt kugleled (5) som nedre kugleled (16).

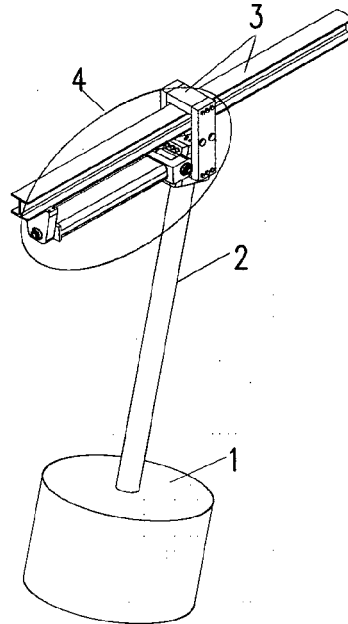
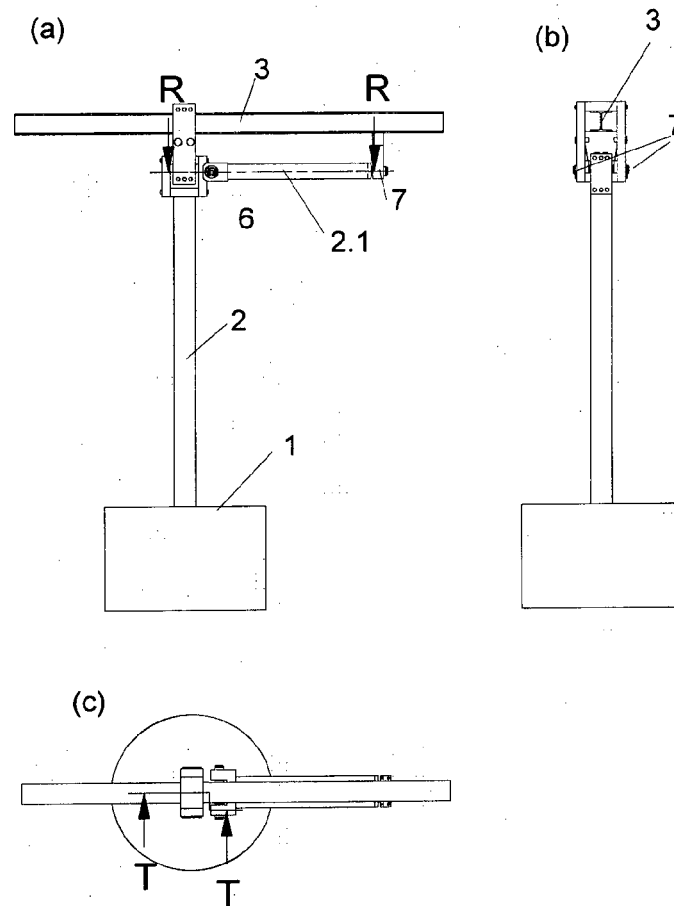
**Fig. 1****Fig. 2**

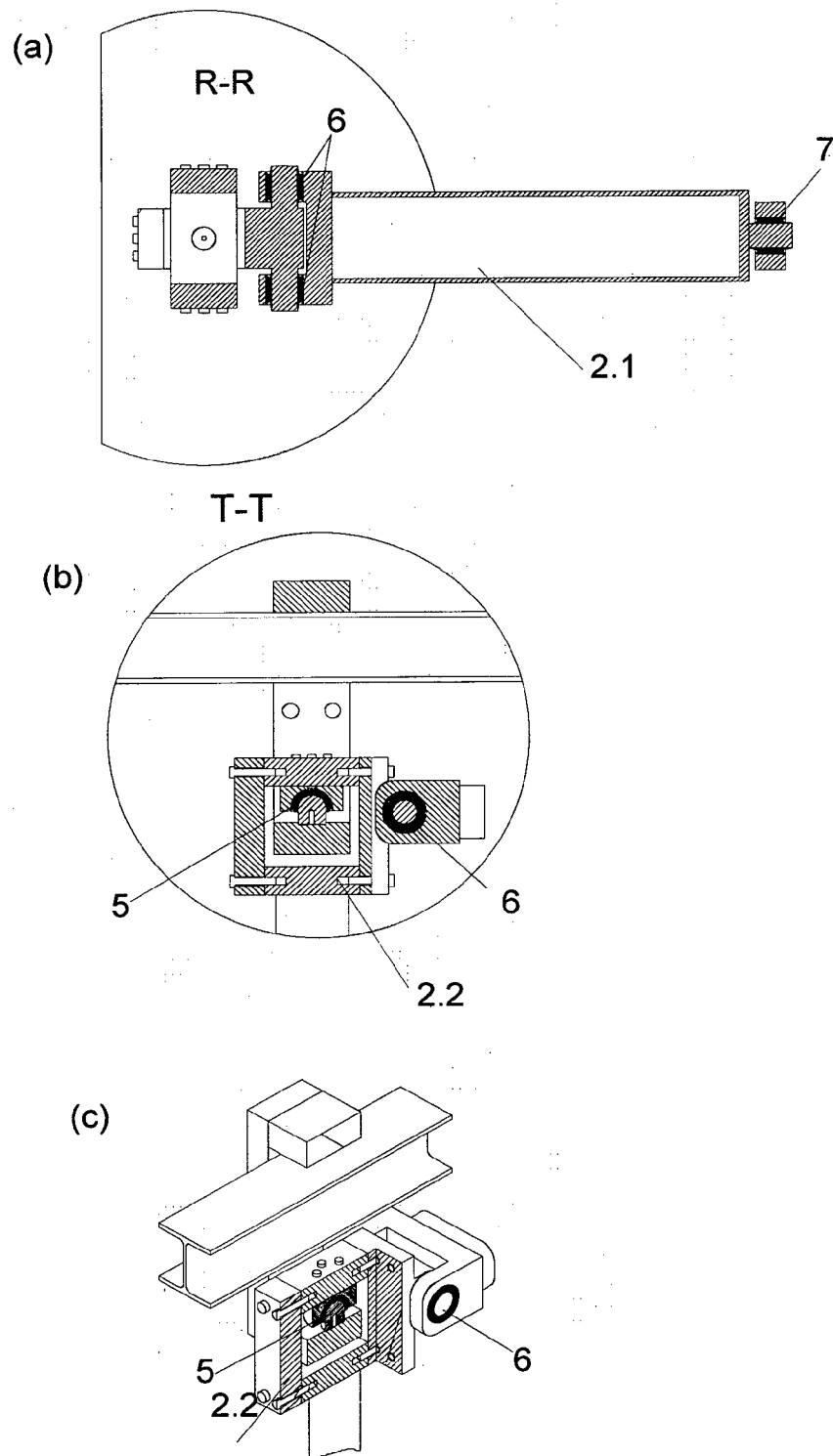
**Fig. 3**

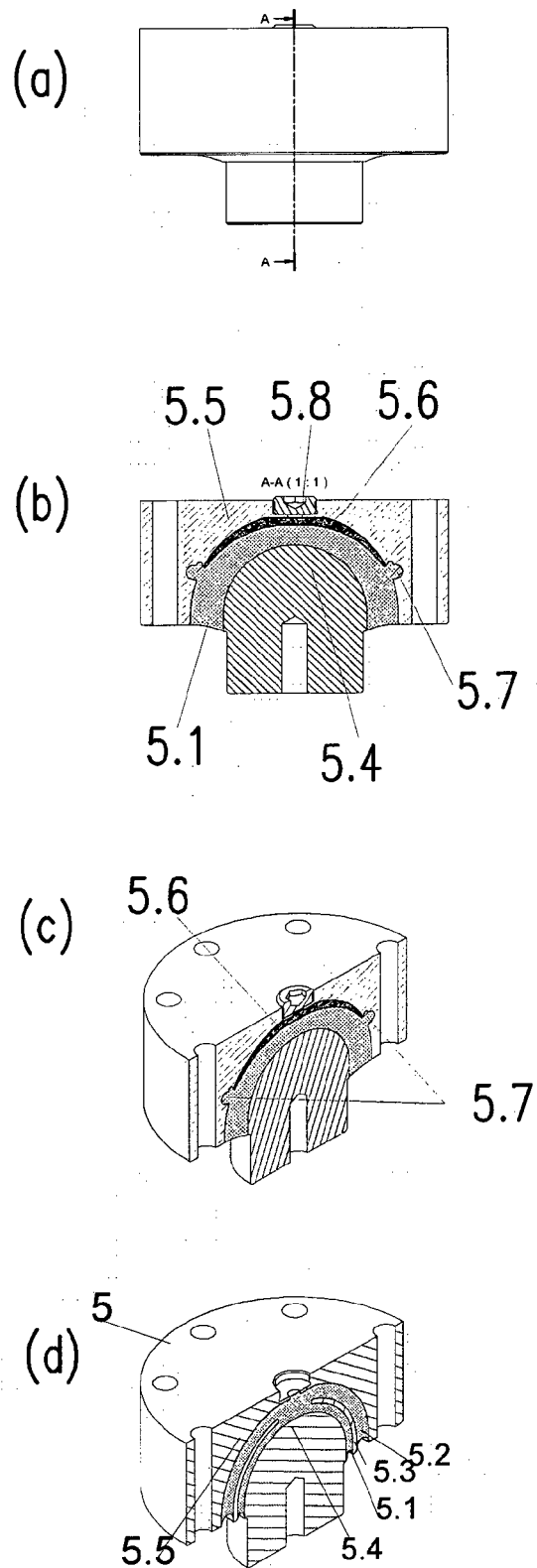
**Fig. 4**

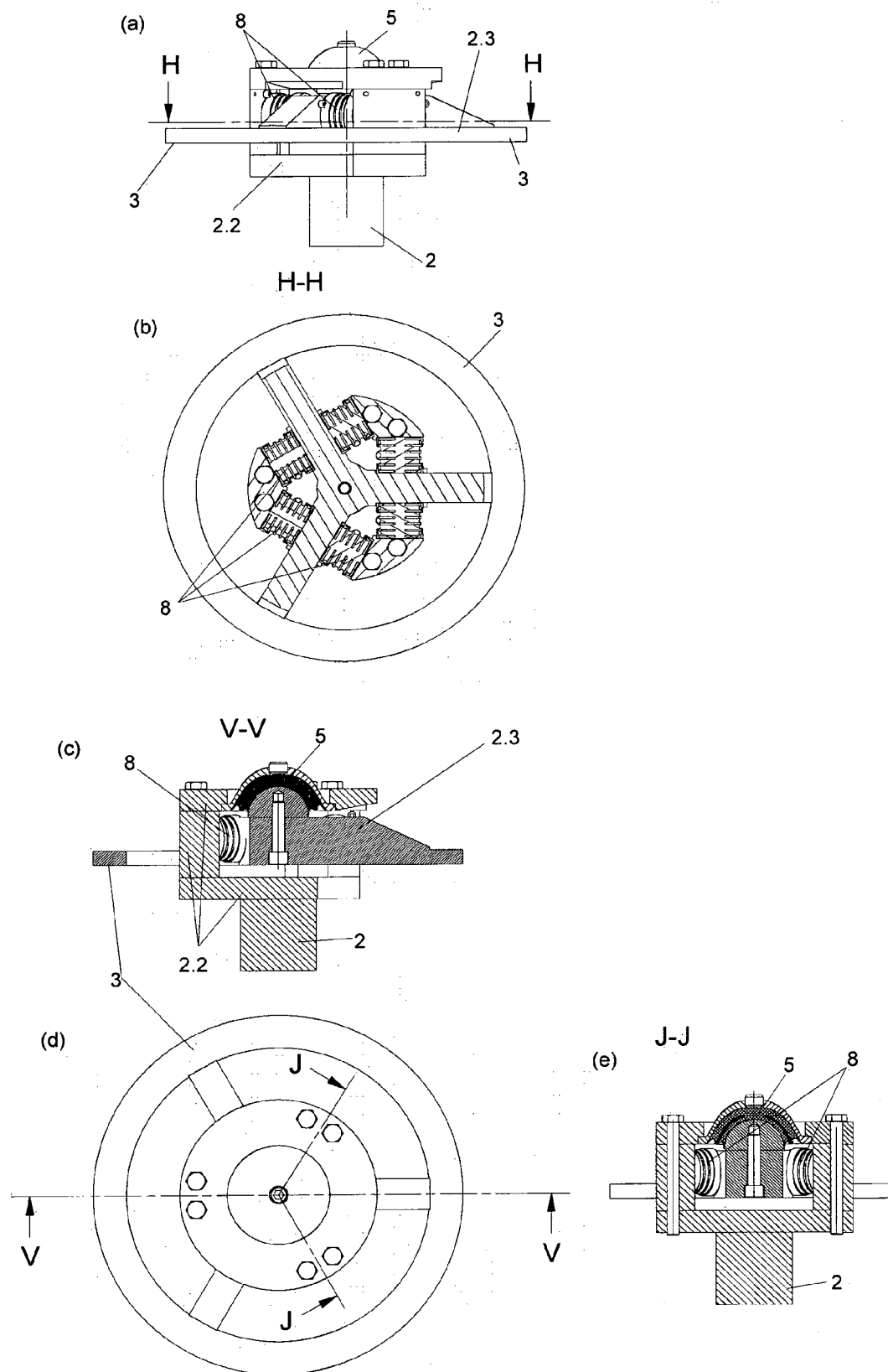
**Fig. 5**

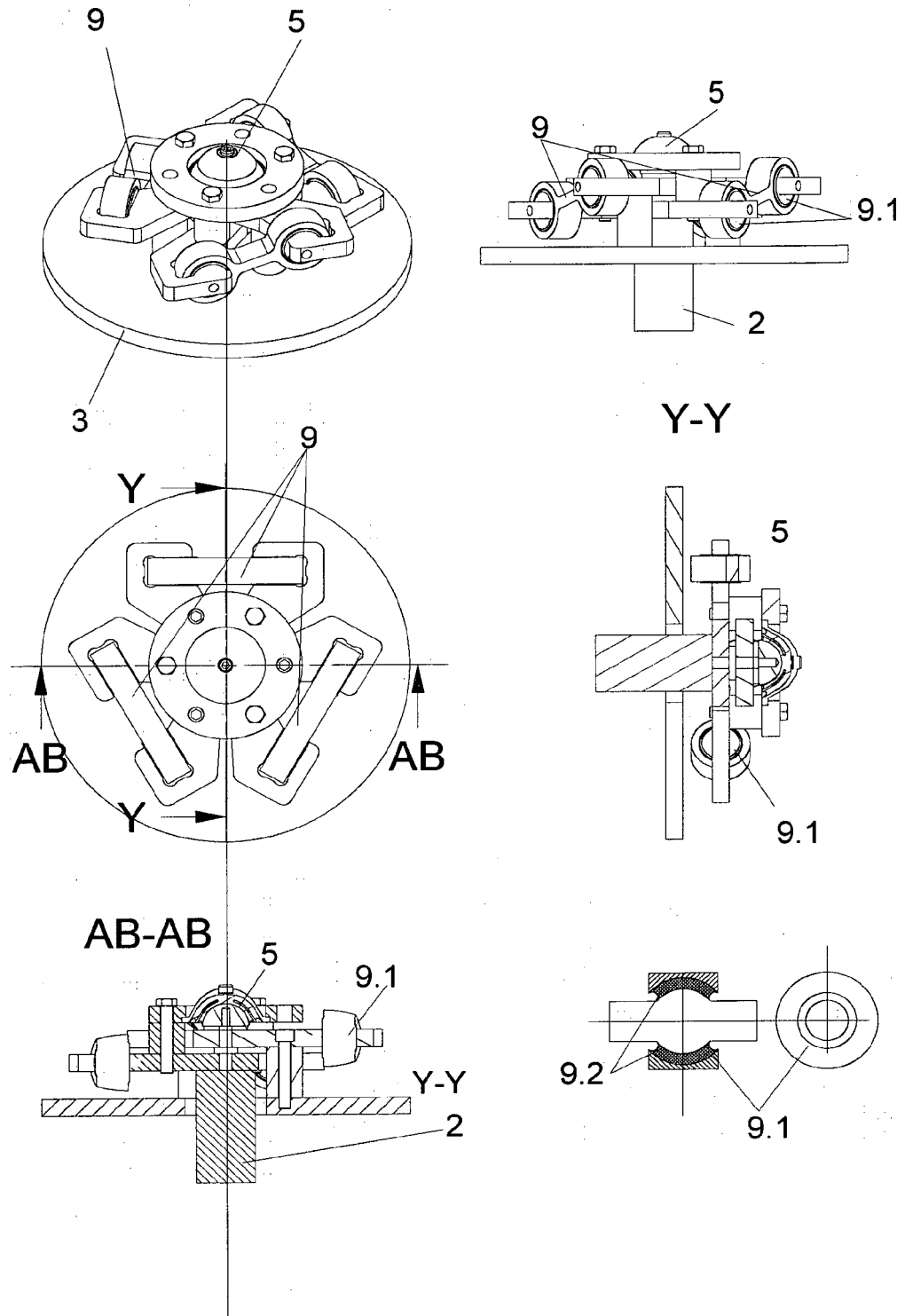
**Fig. 6**

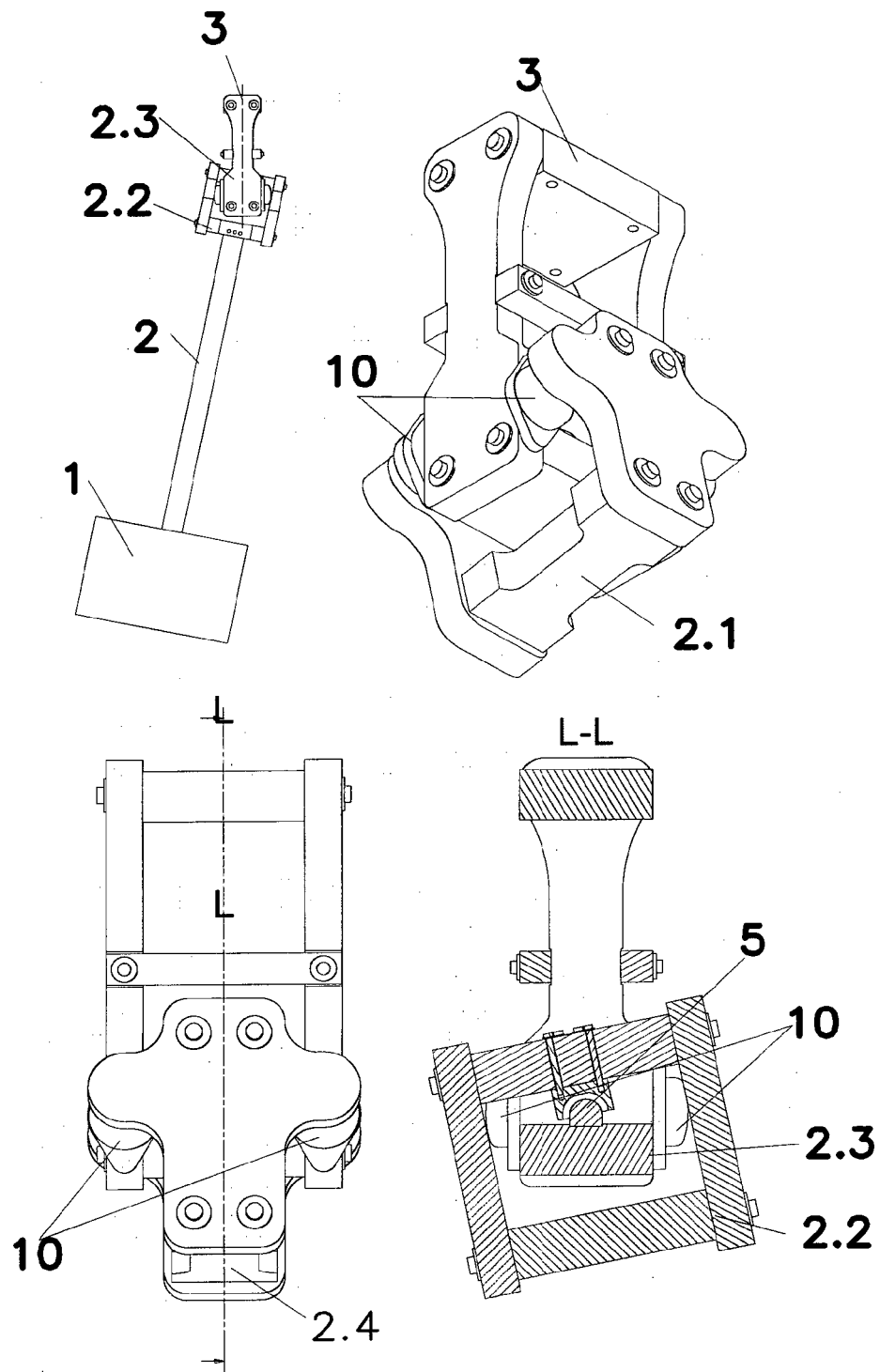
**Fig. 7**

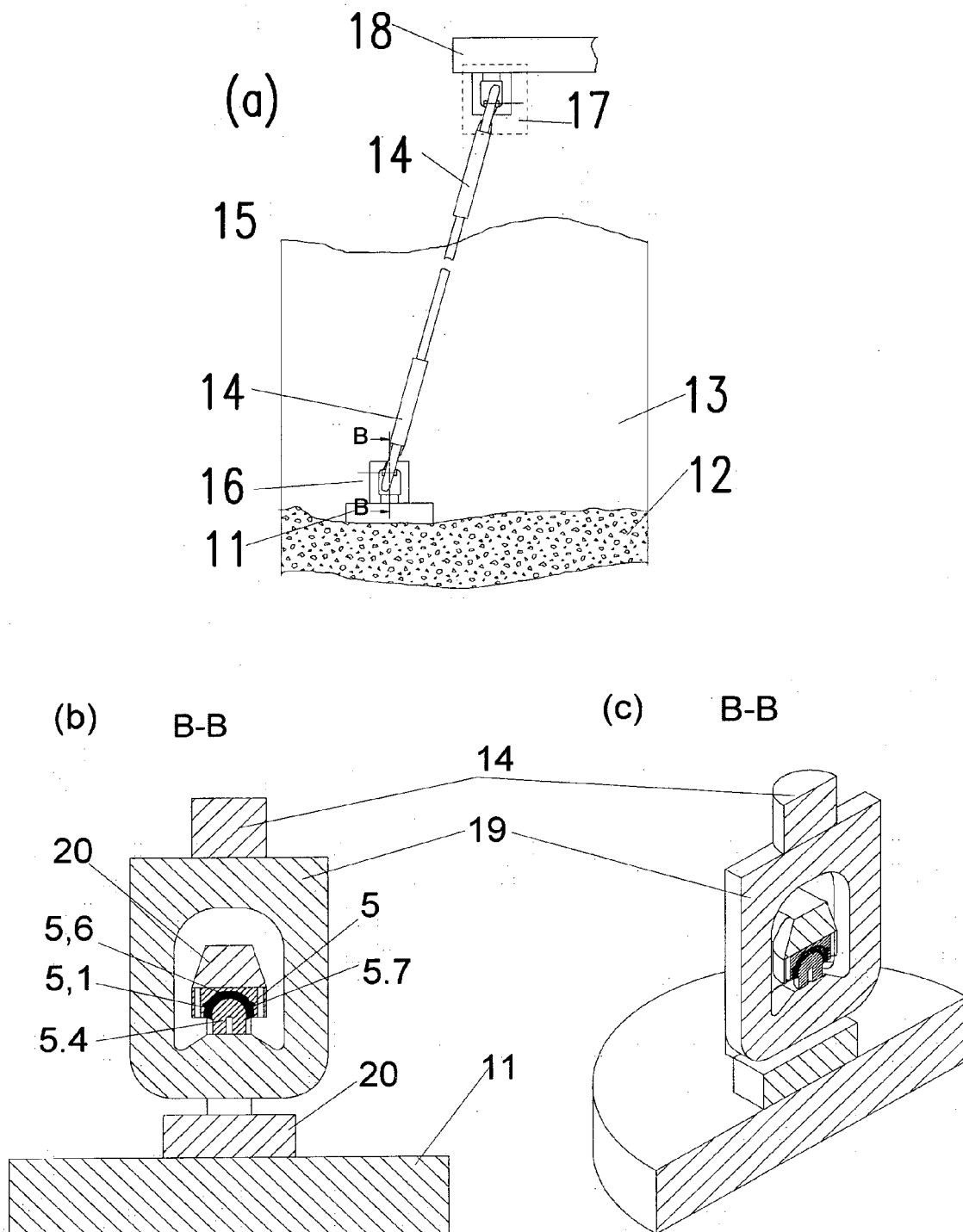
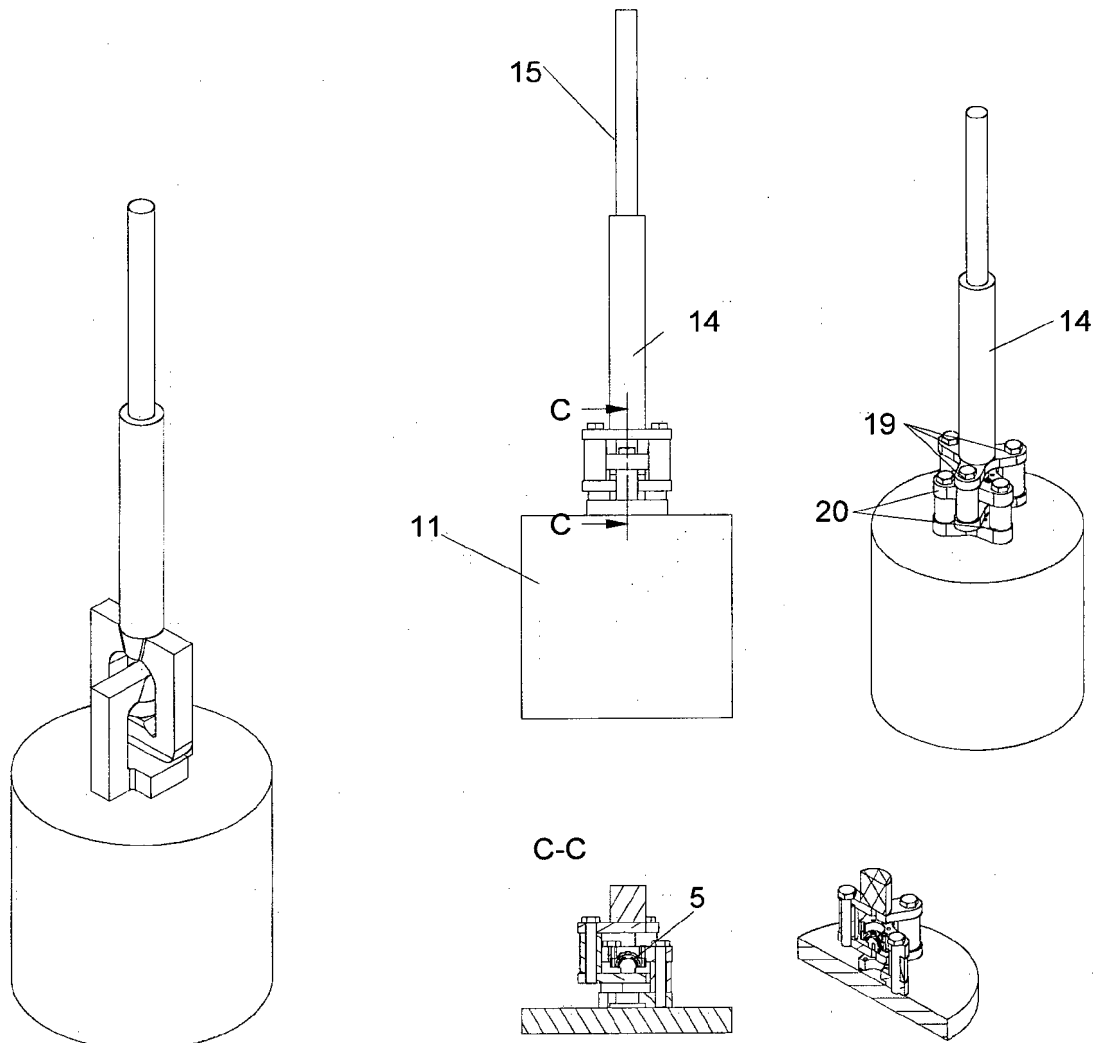
**Fig. 8**

**Fig. 9****Fig. 10**